

On Their Children's Backs: Technological Change in the
Fife Coal Industry, 1750 - 1914.

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DECLARATION

The undersigned hereby declares that the thesis
herewith has been composed by himself and that
the work which led to it is his own.

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ABSTRACT

Our thesis is a case study in historical geography which examines the process of technological change in the Fife coal industry during the period of its greatest development. Each stage in the coal-getting process is examined in turn, from initial prospecting to the eventual shipment of the coal to market. The empirical evidence is considered from two viewpoints. First, the relationship of technological innovation with regional development, with particular reference to population growth and transport infrastructure. Second, in seeking a coherent explanation for the process of technological change in the coal industry, it is suggested that one of the influences at work may be the long-term business cycle. In summary, our thesis seeks to clarify the role of technological change in the developing historical geography of an important Scottish coalfield during the period of its most rapid progress.

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INTRODUCTION

"However incredible it may be, yet I have taken the evidence of fathers who have ruptured themselves from straining to lift coal on their Children's backs."

Children's Employment Commission, 1842

What follows is an analysis of how coal mining in Fife evolved gradually from an industry largely dependent on the back-breaking toil of human beings to one in which the inanimate powers of steam and electricity were harnessed by a sophisticated technology as part of a relentless drive to develop the rich minerals underlying the Southern part of the county. Our aim is to make a case study in historical geography which will illuminate two issues of considerable interest to the geographer and economist of the present day.

First, the effects of technological innovation on regional development are exercising minds at a time when the implications of the microelectronic revolution are becoming particularly apparent. Second, a period of sustained economic depression has seen a re-awakening of interest in the idea of the long-term business cycle, for which technological innovation is a possible, if controversial, explanation.

In our case study, the emphasis must be on the empirical evidence rather than on the theoretical debate, and although documentary evidence is superabundant, there exists as yet no wide-ranging study of the history of mining technology in Fife. Consequently, our approach must be to first provide a comprehensive account of technological change in the county's mines, and then see how far our evidence can help to throw some light on the two main issues which we have identified. Conversely, we will also consider how far the Fife situation may be explained by viewing it from the theoretical perspective.

The years between 1750 and 1914 were chosen because it was this period which saw major growth in the industry and also encompasses most of the major innovations. We will consider the main innovations for each stage of the coal-getting process, from the original prospecting for coal through to the transportation to market, and we will try to assess how far these technological changes were responsible for the changing historical geography of Fife. We will also find some evidence to suggest that technological innovation in the Fife coal industry may be partly explained by the Kondratieff cycle.

CHAPTER 1 - WINNING THE COAL

PHYSICAL BACKGROUND

Rocks of the Carboniferous period occupy the greater part of the Midland valley of Scotland and attain their maximum thickness in Fife. Despite there being five principal formations in the County, only two of these contain the majority of workable coal seams, and their distribution and nature have consequently been a major influence on the developing geography of the coal industry in Fife.

The upper formation is the Productive Coal Measures, which comprises up to 1700 feet (518 m) of strata with about 16 coals from the Pilkembare down to the Lower Dysart seam. These Coal Measures appear in the Eastern part of the coalfield where they are roughly centred on the Wemyss area (see figures 1.1 and 1.2). Separated from this formation by about 1000 feet (305 m) of Millstone Grit are the lower coal-bearing strata, the Carboniferous Limestone Series, which contains the rich Limestone Coal Group. This Group appears in the central section of the coalfield and where development is best there may be up to 16 seams of workable thickness.

It will be seen from figure 1.1 that the main body of the Fife coalfield extends from the outcrop of the Millstone Grit in the West, through Central Fife to terminate on the Forth coast around Lower Largo. The Southern boundary is marked in the East and West by the Forth coastline and in the centre by the outcrop of the Dunfermline Splint seam, while the Northern boundary is recognised as the Ochil Fault and, further East, the Durie Fault. However, the small amounts of coal present in other rock formations has meant that a number of isolated and disturbed coalfields are to be found far to the East of Largo and considerably to the North of the Ochil and Durie Faults. Thus while

we may justify a concentration on the 'main' coalfield area because this is where most of the long-term mining took place, we should not ignore the lessons to be learned from the short-lived exploitations in the North-East of the County.

The Burntisland and Balmule anticlines divide the main coalfield into three sections, East, Central and West, and the historical development of mining in each of these areas has been to some extent influenced by the local physical conditions. For example, the fact that the East and West sections are coastal was an encouragement to 17th-century mining operations both at Culross and at Wemyss, when both places must be recognised as centres of innovation in mining technology. Clearly, some of this was due to the entrepreneurial personalities involved, but a prerequisite for development must have been the proximity of good quality coal seams to the shipment facility.

In looking more closely at the seams themselves, it may be that their characteristics can be related to the process of technological change. For example, the prevalence of thin seams in a particular area may have been an encouragement to the adoption of longwall working or machine mining while the same feature could have discouraged the employment of horses for underground haulage due to the need for higher roadways. In order to investigate this possibility an attempt was made to calculate the average thickness of seams in different parts of the coalfield. It quickly became evident that considerable variations in thickness occurred even within a short distance. An example appears in a description of the North Falfield coal given in the Old Statistical Account, where one seam:

" is 9 feet thick for 60 yards, then gradually diminishing for about 60 yards, till it comes to 5 feet thick, where splent becomes perceptible.....till its thickness becomes 4 feet, where the coal is cut off by a hitch....."

Despite this kind of variation, and the consequent difficulty in comparing average thicknesses, Crowe generalised, and identified the Productive Coal Measures as having about the same total thickness of coal as the limestone but with thicker individual seams². Jevons, too, was able to describe the Limestone coals as being comparatively thin near the coast at Kirkcaldy but getting thicker to the West, where the Lochgelly area sees their maximum development. West of Dunfermline the seams become thinner, but with many remaining workable right up to the outcrop of the Millstone Grit³. This question of seams 'remaining workable' is the main issue in seam thickness. If a seam was too thin to be mined by the techniques available at the time, then from the point of view of regional development, it might as well not have been there at all. On the other hand, if a technical innovation like Longwall working was able to render that seam economically workable, or where a thin seam could be worked together with an adjoining ironstone or fireclay, it could well influence the pattern of mining in that part of the coalfield.

Since it would be helpful to have some idea of how thin a seam had to be before that characteristic made it 'unworkable to profit', an examination was made of the detailed section given for the Wallsend Pit, Dunfermline, in the New Statistical Account for that parish⁴. We are told that several beds of coal were so thin that they could not be wrought to advantage and, from measurements given, it is possible to deduce which beds these are. Out of 27 beds given, 8 were too thin to work, the remaining 19 being wrought in 13 divisions or 'seams'. All 8 of the 'unworkable' beds are less than two feet (0.61 m) thick, while one bed of exactly two feet (0.61 m) appears to have been workable. Also, thin beds of less than two feet (0.61 m) were worked as one seam

when separated from each other by only a few inches of strata. We may conclude from this example that when a bed of coal of less than about two feet (0.61 m) had to be worked as one seam, the techniques employed at the Wallsend Pit of 1844 could not allow this to be profitably done.

Some confirmation that this figure is about right comes first from Jars, who found that in the North of England about 1765, seams less than about $2\frac{1}{2}$ feet (0.76 m) thick were considered to be not worth working⁵. Second, we may look at the Old Statistical Account for Carnock, written in 1794, where preparations were under way for working two seams of coal of only 2 feet 10 inches (0.86 m) and 3 feet (0.91 m). They had been little wrought as a result of their depth, which put them under a drainage level, rather than their comparative thinness, and this suggests that seams not very much thicker than 2 feet (0.61 m) were readily workable around the end of the Eighteenth Century. However, their quality was good and this could compensate for any difficulties found in working⁶.

In Falkland parish some 40 years later, thinness and inferior quality were combined so that the three beds of coal were unable to pay the expense of working⁷, yet at nearby Balbirnie, the Upper coal was mined despite being only 18 inches (0.46 m) thick:

"...the difficulty of sufficiently enlarging the galleries, from the nature of the strata in immediate contact with it, being very considerable, the men suffer severely from a confined and hampered position,....."

Also at Balbirnie we find a useful illustration of the 'divided seam' problem. We have seen that at Wellwood, thin beds sufficiently close together could be worked as one 'seam'. At Balbirnie, the intervening strata became so thick and so hard that abandonment was

the inevitable result. This coal was anyhow of poor quality, which must have contributed to its being given up⁹. At Kirkcaldy, however, a 5½ foot (1.68 m) seam continued to be worked, despite being composed of two beds divided by 15 inches (0.38 m) of clay. Although the expense of working was much increased, this cost had to be absorbed by the proprietor because of competition from other pits nearby and the coal was sold at the normal rate¹⁰. Other examples of thin seams being worked along with concomitant strata are to be found at South Comrie, where the Parrot Coal working totalled only 18 inches (0.46 m) in thickness¹¹, and in a proposed working at Randerston in 1824. In this latter case a Mr Duncan was prepared to work a seam of about one foot (0.30 m) together with an underlying one foot six inches (0.46 m) of fireclay, thus giving a total excavation of two feet six inches (0.76 m). Bald proposed a trial pit but was pessimistic about the viability of such a working:

"it is in few cases a coal one foot thick can be wrought to profit, and that its being wrought in the lands of Randerston of such thickness would depend on the price which could be obtained for it on the coal-hill and should the trial recommended prove the coal to be only one foot thick, I am very doubtful, how far this could be made to yield a return, as the oncost attending the working of a coal so thin will be very considerable."¹²

In other words, only a high quality would justify the costs of working such a thin coal, Fireclay or not.

The quality of the Fife coals is quite variable, and while this aspect of a seam is of course locally important, there is only one major generalisation of real value to our present purpose. Although Fife had many good Household and Steam coals, none were very suitable for coking, so the Iron industry, potentially a huge market for the developing coal mines of the mid Nineteenth Century, never provided the Fife coalmasters with the long-term demand which

encouraged investment in technological advance in other coalfields. However, we must recognise here that the quality and extent of the Fife iron ore reserves were an additional limiting factor, probably even more important than the absence of good coking coal. Thus it was the 'Household' and 'Navigation' (steam-raising) coals which were the main instruments in the Nineteenth-century expansion of the Fife industry. For example, in the three decades up to 1836 the growing demand for coal for steam navigation led to a considerable extension of mining in Dalgety parish, where there was an ample supply of the finest coal for that purpose¹³. Later in the century, the discovery in 1897 that the Dunfermline Splint and Five Foot seams in the Aitken Pit were of Navigation quality, together with similar coals at Bowhill, Lumphinnans and Valleyfield, created a new stimulus to development - in Cunningham's words "opened up a new trade" - in the County of Fife at the end of the Nineteenth Century¹⁴. The Navigation coal was in such demand that within three years of its discovery in the Aitken, that colliery was producing it at over 1500 tons (1524 tonnes) a day.

Of course, the quality of the coal was affected by the presence of volcanic intrusions in the form of sills and dykes. In a letter to Cadell dated 1834, Ronaldson disputes the former's attempt to withdraw from a lease of Torry coal, entered into in the belief that there was a seam in those lands consisting partly of 'Parret' coal. Cadell had found no 'Parret' and Ronaldson points out that Cadell had accepted a risk in that he had "sunk for a precarious seam like that of Parrot so near a dike where there was a great probability of the quality of the coal being changed or deteriorated."¹⁵ At nearby Blair a dike which cut one of the seams near the pit had changed altogether the

quality of the coal, but whether or not this was a deterioration is not reported¹⁶. However, we do know that at Fordell a deterioration was experienced in very few instances. In fact, the reverse was usually the case. On approaching a dike the coal became harder and more difficult to work, often necessitating an extra expense for labour¹⁷. At Kelty, too, when sills had slightly burned the coal, particularly in the Five Foot and Splint seams, thus making it very suitable for 'Navigation' purposes¹⁸.

An additional benefit sometimes gained from dikes was their relative impermeability, which means that they could act as a convenient barrier to water flowing from one group of workings to another. The Old Statistical Account for Dunfermline claims that they "...are often of great use in keeping off the water from the neighbouring mines"¹⁹, but the only specific example known in Fife is the dike which divides the Leven and Durie coalfields, so that the Leven Colliery was protected from the water which had flooded the workings at Durie²⁰.

Dikes were often troublesome, however, by helping to make the coal 'scarce worth working' at places like Burnturk and Clatto²¹ and causing bother in the working of the coal at Kirkcaldy²². One problem in this respect was that a dike could produce a considerable displacement of the strata. Sometimes, in the words of the Old Statistical Account for Dunfermline, 'they raise the coal to the very surface, and at other times, sink it to an unapproachable depth'²³. A good example of the former is found at Halbeath, where dikes had upthrown the strata to the North, thus keeping the dipping seams within easy reach of the surface²⁴. (See figure 1.3). Generally, however, such displacement was more commonly associated with faults.

Where the displacement was small, it raised no great difficulty in working. For instance, the 'hitches' (faults) found in the Balbirnie field about 1840 offered little serious obstacle to the mining operations²⁵, but on the other hand, the faults at Grange were a constant source of anxiety:

"It was full of 'faults' and 'hitches'. It could only be worked at very considerable expense, and was always liable to sudden failure from the disappearance of the coal-seam, which, in past ages, had been dislocated and thrust aside by volcanic action, so that fresh pits had to be sunk where it was judged the coal would be found; while there was always the secret apprehension, which no scientific assurance could altogether stifle, that some day the capricious treasure might vanish entirely." ²⁶

It was in unreliable areas such as this that accurate prospecting methods could prove their value, but the advance of pumping machinery was perhaps the most useful group of innovations to be set upon a 'fault' problem. This is because faulted areas were much more liable to flooding. The 1731 water engine at Balgonie, for instance, was overpowered by the accumulation of water from hitches²⁷, and Goodwin claims that the multiplicity of faults in the East Fife area is responsible for the large amounts of water found underground there²⁸. In general, faults were associated with changes in the depth and thickness of seams while dikes were more likely to have an additional effect on the quality of the coal. Both features are common throughout the Fife coalfield where they continued to challenge mining techniques throughout our period. Even in 1914, the Chairman of the Fife Coal Company could remind his Board that future developments by the Company in Central Fife might be hindered by the amount of faulting present in the strata. Technology had become able to cope with the problems which the geology produced but had to work within the bounds set by the nature of the strata. The physical background

to the Fife mining industry was at once a stimulus to innovation and a determinant of what was possible. In order to assess what the possibilities actually were, the coalmaster had to employ one or more of the prospecting techniques which were available at the time, and it is to these that we now turn our attention.

PROSPECTING

The first stage in seeking a workable coal seam was for many years the simple expedient of examining the land surface, in which the appearance of an outcrop could be an invaluable clue for the prospector. This technique was documented from Elizabethan times until well into the Nineteenth Century. Nef, for instance, points out that during Elizabeth's reign, an outcrop "beinge founde they search which way the vayne leaneth and on the contrarie side they beginne to sinke"²⁹. Clerk, writing in 1740, advocates a close look at water courses and valleys as well as the observation of springs:

"for if such leave behind them a yellowish substance or Ocher, and at the same time, taste of rusted Iron, they probably come from a seam of coal, but this is a rule, which will not always hold good, for tho' I know no coal seam, but what yields more or less of such water, yet I have known of this kind of water proceed from a Sulphurious Moss or Till,³⁰ or from seams of Iron of no great value or thickness."

Here lies the implication that an examination of the surface, no matter how thorough, could not be relied upon for accuracy. This danger is again hinted at by Bald nearly a century later when he, too, recommends the examination of rock exposures in river beds as well as the evidence to be found in spring water³¹. However, the dangers of this kind of superficial examination are best illustrated by specific examples. About 1790, for instance, some Englishmen thought that

workable coal was to be found under the parish of St Andrews and St Leonards, "judging from the appearance of the ground". They accordingly entered into several contracts but after spending a good deal of money on boring, were disappointed to find no coal of any value³². Over 30 years later, Mr Duncan's offer was made to work coal on the lands of Randerston, St Andrews, believing that a coal was exposed to view in a section of strata at the sea shore. Robert Bald could find no trace of it when he examined the area in October, 1824, and decided that if coal existed, it must be at a considerable depth. However, since a thin coal had been worked on a neighbouring estate, Bald concluded that an inexpensive trial pit was a worthwhile project to settle the question whether workable coal was to be found³³.

Where the alluvial cover was not thick, an open trench could be dug to expose outcrops of strata, but although this was recommended both by Clerk and Bald, it was most useful for Edge seams (steeply inclined strata) and we have no record of its application for coal prospecting in Fife. An alternative was to sink a trial pit, but this tended to be costly, despite Bald's readiness to use one at Randerston, because of the necessity to pump out water and the need for timber supports. Even a pit of only 15 or 20 fathoms (27 or 37 m) could be expensive, and Clerk prudently recommended that trial pits be sunk only where they could be turned into working pits if coal was found, where the coal was likely to be workable without the need for expensive pumping machinery, and where a market was within easy reach³⁴.

The only alternative to trial pits was boring with metal rods, which tended to be cheaper but was less accurate. In the "troubled" strata at Torry, for instance, Landale proposed to prospect for the

Ironstone by running a day-level (tunnel) from the nearby burn, and by sinking a pit. He thought that: "no other plan will prove it so satisfactorily, because Torry is so troubled (dislocated) that we could not trace it out with bores with any thing like satisfaction...." ³⁵. Even the advantage of cheapness had its limitations in the early days of boring. Sinclair found deep bores as tedious and expensive as sinking a pit, due to the need for a frequent drawing (raising) of the rods ³⁶. This reservation will be better understood when we have a clearer picture of the actual method of boring.

Boring in England was known in the Newcastle area as early as 1618 and by 1636 it was in use at Wemyss, Fife, where it was carried on by Walter Greame, an Englishman. Bores were sunk not just from the surface but also from the bottom of pits and were sometimes employed to bring air down to a day-level or to drain a ventilation pit being sunk to one ³⁷. According to Gemmell, boring had not been used by 1657 for discovering or draining the old and dangerous drowned workings which were quite common even then ³⁸. A possible reason for this is that a satisfactory method had not been developed for operating a set of boring rods in a horizontal hole within the confined space of a Seventeenth-century coalwork.

By the mid Eighteenth Century, regular borings were being taken on the Rothes estate and these may be regarded as part of a process of expansion throughout this busy period in the life of the Rothes pits ³⁹. These bores were shallow, however, and reflect the 'extensive' nature of the Fife industry at that time, compared with the 'intensive' exploitation of the late Nineteenth Century. For example, a bore put down for Lord Rothes in Auchmuty ground in July, 1743, was only "sunked three fathom of Earth and boared nine fathom

one foot and six inches to ye pavement of the coal" ⁴⁰. It seems here that the expedient had been adopted of sinking through the soft cover but boring the hard strata. Although a bore of some 9 fathoms (16.5 m) is very shallow, the technique had the capacity to go much deeper, and Clerk implied in 1740 that boring to 20 fathoms (36.6 m) - "a reasonable depth" - was a satisfactory alternative to sinking a trial pit ⁴¹. Referring to the North of England in 1765, Jars states that the greatest depth attained by bores was 600 feet (183 m) ⁴².

The actual method of boring to depths even considerably in excess of these is quite simple, and changed hardly at all between the descriptions published in the "Compleat Collier" in 1708 and in Leifchild's book of 1862 ⁴³. The boring rods were made of wrought iron, about one inch (2.54 cm) square in section and normally three feet (0.91 m) long. They could be screwed together and were supported in the hole by a timber tripod 20 or 30 feet (6.1 or 9.1 m) high. A chisel bit did the cutting as the rods were pulled up then allowed to fall back into the hole. At the same time, this percussion was combined with a turning motion produced by two labourers working on a cross-piece. Rods were added as the hole gradually deepened and samples were periodically brought up by substituting a wimble or sludger - a kind of hollow tube - for the chisel bit. (See figure 1.4).

While two, or possibly four, labourers could handle a set of boring rods in a bore only a few fathoms in depth, the greater depths being prospected in the early Nineteenth Century led to the need for a more powerful lifting apparatus:

"When bores are only to be a few fathoms in depth, the whole operation is performed by manual strength; but when a deep bore of any consequence is to be made, a set of lofty triangles of wood is placed over the bore-hole, with a pulley at top, through which a rope is passed; one end is connected with a crane or windlass at the surface, to the other end, an oval iron ring, named a runner, is attached; by these means the rods are drawn up and lowered down with great facility." ⁴⁴

By mid century, a horse-gin or steam engine might be employed in sinking deep bores but we do not have enough evidence in Fife to adequately test Buxton's opinion that by mid Nineteenth Century, all boring machines utilised steam power⁴⁵. Both Leifchild in 1862⁴⁶ and Jevons in 1915⁴⁷ imply, but do not make explicit, that this was probably not the case. It may be that Buxton's view is partly based on a comment by Forster Brown:

"All the boring machines at this time (mid Nineteenth Century), which were required to reach a considerable depth, appear to have been driven by steam power"⁴⁸

Brown's implication is that shallow bores might be sunk using a less powerful driving agency. However, rotary boring was patented first in 1862, and was a system in which the hole was made by the rapid rotation of a cutting ring. This lent itself ideally to steam power, and had the additional advantage of providing an unbroken core of strata, which helped to eliminate a major inaccuracy of boring by the percussive method where the strata was extracted in a broken, even pulverized, state. This was a real benefit to a coalfield like Fife where prospecting by bores played such an important part in the development of the industry.

For example, Beaumont recommended a bore at a specific location in his report on Blairhall Colliery in 1815⁴⁹, and five years later at Fordel, Bald felt that two bores were necessary, since the pit was so much surrounded by 'troubles' in the strata. Only after the boring had been completed would it be possible to determine which line of operations to adopt⁵⁰. In 1852, a lease of Lumphinnans Colliery obliged the tenants to explore by boring certain specified areas to a depth of not less than 80 fathoms (146.4 m)⁵¹. By 1872, it was a question of "considerable moment" at Kelty whether or not a railway

extension and the development of the Western Coalfield should proceed immediately. To settle the question, bores had to be put down to prove the condition of the Dunfermline Splint Coal. Since a number of bores were involved here, this major investment decision would not have depended on insufficient or inaccurate data⁵². However, at South Comrie the coalmaster had a less happy experience. In 1855, Alexander Henderson had put down a bore for the coalmaster, A.C. Wellwood, and had found the Parrot Coal to be 10 inches (25.4 cm) thick at a depth of 30 fathoms (54.9 m). In 1866 the then tenant deepened the Bank Pit to that level and found the seam to have an average thickness of no more than 3 inches (7.6 cm). While this "very serious blunder on the part of the borer"⁵³ was not the only factor involved, it must have been at least partly responsible for Williamson finding in 1867 that the pit was evidently running at a loss⁵⁴. In this case we do not know if Henderson, the borer, was an experienced man, and we must question too the expertise of the borers working for Henrietta Keddie's father at Grange Colliery, sometime in the 1840's:

"In boring to ascertain the exact situation of the coal-seam for which the pits were to be sunk, the borers passed through a layer or bed of ironstone, the nature of which was undetected. It was not recognised then either by the workmen or by my father. Had it been known it would have probably altered entirely the story of the pits and of all connected with them."⁵⁵

Bald certainly seemed to think in 1830 that Scotland suffered from a lack of professional borers, though master sinkers could sometimes perform this work accurately⁵⁶. Perhaps it was one of these men he had in mind when at Fordel he proposed to engage "a person of experience to put down bores, upon whose accuracy we may rely."⁵⁷ At any rate, it seems that from about 1740 onwards, the earlier Scottish reliance on Tyneside boring expertise was gradually being reduced, although in Scotland it was more common for the skills of boring and sinking to be

combined than was the case South of the border.

Although boring could prove expensive, as at St Andrews about 1790 when the English entrepreneurs found their optimism unjustified⁵⁸, or at Torry, where the proprietor incurred "considerable expense" in making borings in 1839⁵⁹, the costs could be justified either by preventing useless expenditure in sinking pits or by finding profitable coal seams, as was the case respectively in these two examples. On the other hand, Bald did recommend the trial pit at Randerston, where he felt the expense would be "inconsiderable", so in some situations a pit must have been preferable to boring⁶⁰. This had been recognised in 1708 when boring cost no more than 15 or 20 shillings (75p or £1.00) per fathom (1.83 m) whereas to sink a pit was between 50 shillings (£2.50) and £3 per fathom and often considerably more⁶¹. However, the price of boring normally varied with depth. About 1830, for instance, it was 6 shillings (30p) per fathom for the first 5 fathoms, and an increase of 6 shillings per fathom for every additional 5 fathoms. viz:

1st 5 fathoms	at 6 shillings/fathom	£1 -10 -0
2nd 5 fathoms	at 12 shillings/fathom	£3 - 0 -0
3rd 5 fathoms	at 18 shillings/fathom	£4 -10 -0
4th 5 fathoms	at 24 shillings/fathom	£6 - 0 -0
<hr/> total 20 fathoms		<hr/> £15 -0 -0 <hr/>

The price was commonly higher when particularly hard strata was struck although the master borer was responsible for supplying and upholding his own boring rods. Despite this, the South Lethans Colliery in 1848 owned its own set of rods. Two sets are inventoried at a value of £34, but we have no way of knowing how closely they correspond to the set shown in figure 1.4⁶².

SINKING

Having identified a workable seam by boring, a shaft had to be

sunk or a mine driven in order to reach it. Sinking was seen in Scottish mining as a specialist task, though often associated with boring. At first, the sinkers were commonly English, but by the 1730's, the Rothes pits were being sunk by men who appear to have been Scots and who were likely to have been ex-hewers. They were more distant from the colliers by 1808, however. Despite being engaged in "one of the most laborious, wet, and dangerous employments that can be imagined.", it was believed that sinkers would have spurned the idea of becoming colliers, even with double wages, "and be not a little astonished how such a proposal could be made to them." ⁶³

The first task which they faced was to get through the soft cover so as to hit solid rock. It was usually necessary to support the sides of this part of the pit with wood, as specified in the agreement for sinking a 20-fathom (36.6 m) pit at Wellwood around 1850, but where running sand was encountered, an 'opencast' method could be employed. Here, a 40-foot (12.19 m) square would be dug out to a depth of perhaps 3 feet (0.91 m) and the sides clad with timber. Successively smaller excavations in the centre eventually got to bedrock, perhaps after three or four stages ⁶⁴. However, this laborious process was largely avoided in Fife. Only at Methil in the mid Seventeenth Century was running sand a problem, and being unable to timber the sides of the pit, the Earl of Wemyss dealt with it by sinking another pit a few feet away and pursuing both shafts alternately ⁶⁵. Although 'cribbing' and 'tubbing' could also be employed in securing the upper part of the shaft ⁶⁶, the literature provides no evidence that the Till overburden in the county was a problem for Fife sinkers. On hitting bedrock, however, they did face the problem of cutting through the hard strata, and the traditional

appliance used here was the 'Stook and Feathers'.

The method was to drill a hole some 2-3 inches (5 - 7.6 cm) in diameter and about 3 feet (0.91 m) deep. The sinker then inserted two long strips of iron ('feathers'), one down each side of the hole. He placed a long wedge ('stook') between them and drove it down with a sledge-hammer, thus cracking the rock. This method had been employed in Seventeenth-century Culross, where feather marks could be seen on a pit exposed in 1968. From these, it appears that one of the sinkers must have been left-handed⁶⁷. Because this method was extremely laborious and expensive, very hard strata was sometimes left as a narrowing in the shaft⁶⁸, but the advent of gunpowder in sinking operations meant that this dangerous practice could be discontinued.

Although gunpowder does not appear to have become common in sinking until the late Eighteenth Century, Clerk was in 1740 well aware of its value in driving mines, perhaps because a lack of suitable fuses was not such a problem in this situation. In a vertical shaft it was more difficult to effect a speedy escape after setting a charge. However, gunpowder was used in sinking a pit at Clunie, Fife, in 1753⁶⁹. The dangers of employing powder in shaft sinking are emphasised by the deaths of two sinkers in a North of England pit in 1776, when the charge went off too soon due to a hot iron ring being run down a guide rope too early⁷⁰. More than 30 years later, Bald points again to this problem:

"every other hour they have to lay a train to gun-powder; and quickly springing to the basket, are drawn up the pit by the aid of machinery, with great velocity to escape being blown to pieces; and, it frequently happens, that the train takes fire ere they have ascended a few fathoms; so that the splinters of stones fly around them in all directions; and the sound of the explosion is so overpowering, as to make the ears tingle, and^d₇₁ suspend the sense of hearing for some minutes;"

Regarding the shape of the shafts, English collieries had a definite tendency to the circular form, particularly in the great coalfield of the North-East. Scottish shafts, however, were circular only up until the mid Seventeenth Century, when stairs became more common than the winding windlass, thus promoting the building of square or rectangular shafts⁷². These became traditional, and the shapes continued to be used in Scotland throughout the Nineteenth Century. This was partly because very deep shafts needed the strength and security of a circle shape, but the Scottish sinkings remained comparatively shallow for many years. Round shafts continued in use as ventilation pits, however. Good examples are to be found sunk on some of the Fife day-levels, particularly those at Urquhart, Dunfermline. In 1820, a proposed ventilation pit at Fordell was to be circular and of 8 feet (2.44 m) diameter so that if workable coal were found in the vicinity it could be drawn to the surface through this pit⁷³. Compare this with the 4½-foot (1.37 m) width of the ventilation pits in Green's plan for Balgonie in 1785⁷⁴.

However, pits other than for ventilation were most commonly rectangular. For instance, Cadell is quite specific about the shape and size of the shaft to be sunk at the new winning on the Barncraig seam, Wemyss, in 1849:

"The pit should be of such a shape as to admit of sufficient room for the pumps and plungers and besides the drawing side to admit of a free passage from top to bottom for drawing or replacing pumps or for descending to examine them." ⁷⁵

Cadell's appended sketch is given in figure 1.5 and shows a rectangular shaft 18 feet 6 inches (5.64 m) by 6 feet (1.83 m) divided lengthways into four sections. About the same time, the specification for the 20-fathom (36.6 m) sink at Wellwood required a rectangular pit 12 feet (3.66 m) by 5 feet (1.52 m) and rounded at the corners⁷⁶,

while a pit to be sunk on a Wemyss ochre seam was 10 feet (3.05 m) by 5 feet (1.52 m) "which pit might eventually answer for a rise pit in working the coal" ⁷⁷.

While it is true to say that the dimensions of shafts had grown with the need to house pumps and haul huge quantities of coal, there is not always a clear progression. Instructions from the Earl of Wemyss in 1657 advised the setting down of a sink 18 feet (5.49 m) by 12 feet (3.66 m), or roughly twice the size of the Barncraig shaft of 1849⁷⁸. Nevertheless, the general trend is established by pits like the Mary, begun in 1902 with a shaft 28 feet (8.53 m) by 11 feet (3.35 m) and the Wellesley, sinking in 1909 with two elliptical shafts 27½ feet (8.38 m) long by 14 feet 10 inches (4.52 m) wide⁷⁹.

These sizes were big enough to allow for the division of the pits by brattices so that ventilation, pumping and winding could be performed in separate sections. Although there are several Fife examples of working pits being divided in this way (see figure 1.5), it is not known how far brattices were employed during the sinking process. For instance, despite four windlasses being employed in sinking the Wemyss shaft of 1657, three for drainage and one for the stones, there is no mention of the shaft being divided by a partition⁸⁰. However, Clerk in 1740 and Bald in 1830 both refer to the practice, with the latter providing rather more technical details of construction⁸¹. Given the fact that brattices would be required in the working pit, it would clearly have been best to instal them as the sinking proceeded, so that sinkers could work free from the risks of falling rubble in the winding compartment, and so that ventilation could be better maintained as depth increased. The shaft lining, too, was emplaced as sinking proceeded.

A lining in the shaft could be required for two reasons. First,

loose strata had to be restrained from falling into the pit, and second, a lining could help to prevent the leakage of water into the shaft. The former was best guaranteed by a stone lining, a fact recognised by the Earl of Wemyss as early as 1677:

"When ye set down this sink I will have no timber cradling in it, but all being of good stone upon the quarrell (rock) head to the strike board for it must be a sink of long endurance" 82

In 1820 at Fordell, Bald was able to echo this instruction when he recommended a pit:

"cradled with stones in place of wood; as it is probable that this pit will have to be kept open for a long period of years." 83

Despite the use of cast-iron tubbing on Tyneside by John Buddle senior in 1792, this lining technique does not seem to have had a great deal of impact in the Fife coalfield⁸⁴. In fact, the few references to shaft lining in the County are to stone or to wood. This suggests that many shafts were left unlined where this was at all possible, or with some lining inserted only where necessary. This was certainly the case in the Wellwood specification of about 1850, where only unsafe strata was to be secured with wood⁸⁵. The problem of water was dealt with here by cutting a 'hassing' (channel) about 7 inches (17.8 cm) wide and 6 inches (15.2 cm) deep down one side of the shaft and faced on the front with boards. Into this hassing the water was carried by ring-channels cut about a foot (0.30 m) deep round the shaft walls and sloping down into the hassing⁸⁶. The early Twentieth Century saw the introduction of concrete linings for the major new sinkings. The Mary had its 1902 shaft lined with this material from top to bottom, thus serving both purposes of securing the shaft walls and preventing the inflow of water⁸⁷.

Although the sinking of wider shafts tended to be more expensive,

the long-term trend in costs is difficult to determine from the Fife figures since the cost of sinking is known for only a small number of shafts in the County between 1654 and 1891. They are listed in Table 1.1, from which three useful points emerge. First, in the early days, sinkers were paid partly in kind, eventually evolving into a system in which payment was in money only, although the coalmaster appears to have been still responsible for finding any construction materials required. For example, in 1654 the Earl of Wemyss contracted with four colliers (not yet referred to as 'sinkers') to put down the Mill Sink at Blair Burn:

"I to give them £20 for every fathom of the said sink from the grass or strike-board till they set me down 10 fathoms also 4 stones of iron, a loan of my quarry mell, and also 4 bolls of oat meal (2 at the first and other two at the 10 fathoms end) and after that I am to agree anew with them or others: But till it be 10 fathoms down, although they should meet with never so much water or hard stone, this is all they get from me; I cradling the sink and furnishing all windlass works." ⁸⁸

By 1753, sinkers agreed to put down a pit at Clunie for £9-10-0

Scots per fathom provided they were supplied with gunpowder, candles and free coal ⁸⁹, and the Balgonie estimates of 1785 by Green and Beaumont refer only to money costs ⁹⁰. It may be that no great quantity of timber or stone lining was required here. The figures given for Dunfermline in 1825 were estimated so as to cover every expense, so presumably the cost of any materials and tools is included in the prices of £15 per fathom (1.83 m) for an Engine pit and £7 per fathom for a Bye pit (winding pit). Although in this case we are not told the dimensions of the shafts, it seems reasonable to conclude from the prices that the Bye pit was by far the smaller in cross-section ⁹¹. The agreement at Wellwood some 25 years later is more specific. Here it was agreed that the sinkers would have all their

timber provided by the coalmaster, who also undertook to supply a set of sinking tools⁹².

A second point which emerges from the table is that costs varied with the function of a sinking. For instance, the three Engine pits on the Rothes lands (nos. 2,3 and 4 in the table) have roughly comparable costs at £2 - 3 per fathom, while the other two pits in that group (nos. 5 and 6) seem to fall into another cost category. While we cannot be absolutely certain about their function, we can be fairly sure that they were not Engine pits. More clear cut are the estimates for Balgonie in 1785. Here, five ventilation pits of only 4½ feet (1.37 m) width were costed at £1 per fathom, winding pits at £2 or £2-10-0 and Engine pits at £4 per fathom. The accuracy of these figures is confirmed by the fact that the two engineers, Green and Beaumont, while putting forward different schemes, agree on their estimates of sinking costs⁹³.

Thirdly, costs were not always a simple amount per fathom, as two Nineteenth-century examples illustrate very well. The Wellwood contract was agreed at £4-10-0 per fathom (including 5 shillings per fathom for the hassing), but with an additional cost of 12 shillings for each drainage ring built in⁹⁴. At Kinneddar in 1891, shaft No. 2 was to be sunk in six months at £21 per fathom but a bonus of £100 per month was payable for earlier completion⁹⁵. Thus on the whole, sinking costs varied quite substantially, especially between pits sunk for different purposes but also over time, where wider shafts promoted a tendency for costs to increase.

In summary, we have seen first how the geological structure acts not only as a stimulus to technological innovation, but also sets limits on the level of success which can be achieved. Secondly, we have seen how prospecting techniques have been used to alert Fife coalmasters to

the benefits and the hazards of exploiting their mineral wealth, though sometimes with limited accuracy. Thirdly, we have examined the process of sinking so that the coal seam may be won. It is probably true to say that in neither prospecting nor in sinking do we find the kind of revolutionary technological change which occurred in other branches of the coal-getting process, but the evolutionary improvements which took place during the period under consideration have been instrumental in interrelating the Fife coal industry with the physical framework in which it had to operate.

TABLE 1.1

SINKING COSTS IN FIFE 1654-1891

	DATE	LOCATION	DEPTH IN FATHOMS (M)	PIT FUNCTION	COST (£ Sterling approx per fthm)
1	1654	Wemyss	10 (18.3)	Drainage	£2.00 plus goods
2	1734	Roths	18 (32.9)	Engine	£3.00
3	1740	Roths	25 (45.7)	Engine	£2.00
4	1741	Roths	18 (32.9)	Engine	£2.25
5	1742	Roths	part		£0.50
6	1753	Roths			£0.75
7	1785	Balgonie	8 (14.6)	Ventilation	£1.00 (Green)
8	1785	Balgonie	20 (36.6)	Winding	£2.00 (Beaumont)
9	1785	Balgonie	28 (51.2)	Winding	£2.00 (Beaumont)
10	1785	Balgonie	48 (87.8)	Winding	£2.50 (Beaumont)
11	1785	Balgonie	48 (87.8)	Winding	£2.50 (Green)
12	1785	Balgonie	30½ (55.8)	Engine	£4.00 (Beaumont)
13	1785	Balgonie	50 (91.5)	Engine	£4.00 (Green)
14	1825	Dunfermline	70 (128)	Engine	£15.00
15	1825	Dunfermline	60 (109.8)	Winding	£7.00
16	1850	Wellwood	20 (36.6)		£4.50
17	1891	Kinneddar	37 (67.7)	Engine	£21.00

Figure 1.1 GEOLOGY OF THE FIFE COALFIELD

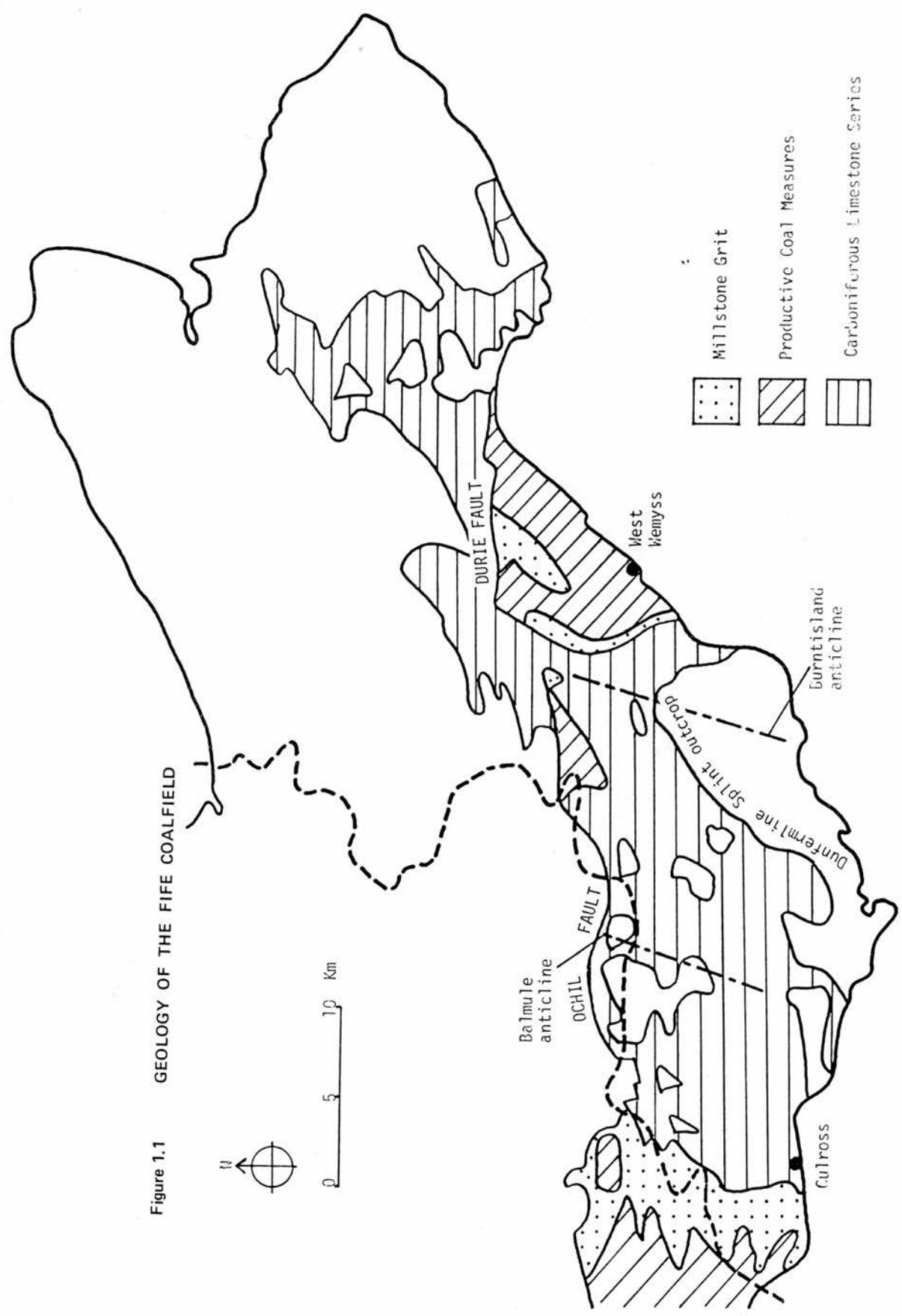


Figure 1.2 GEOLOGICAL CROSS-SECTION OF THE FIFE COALFIELD

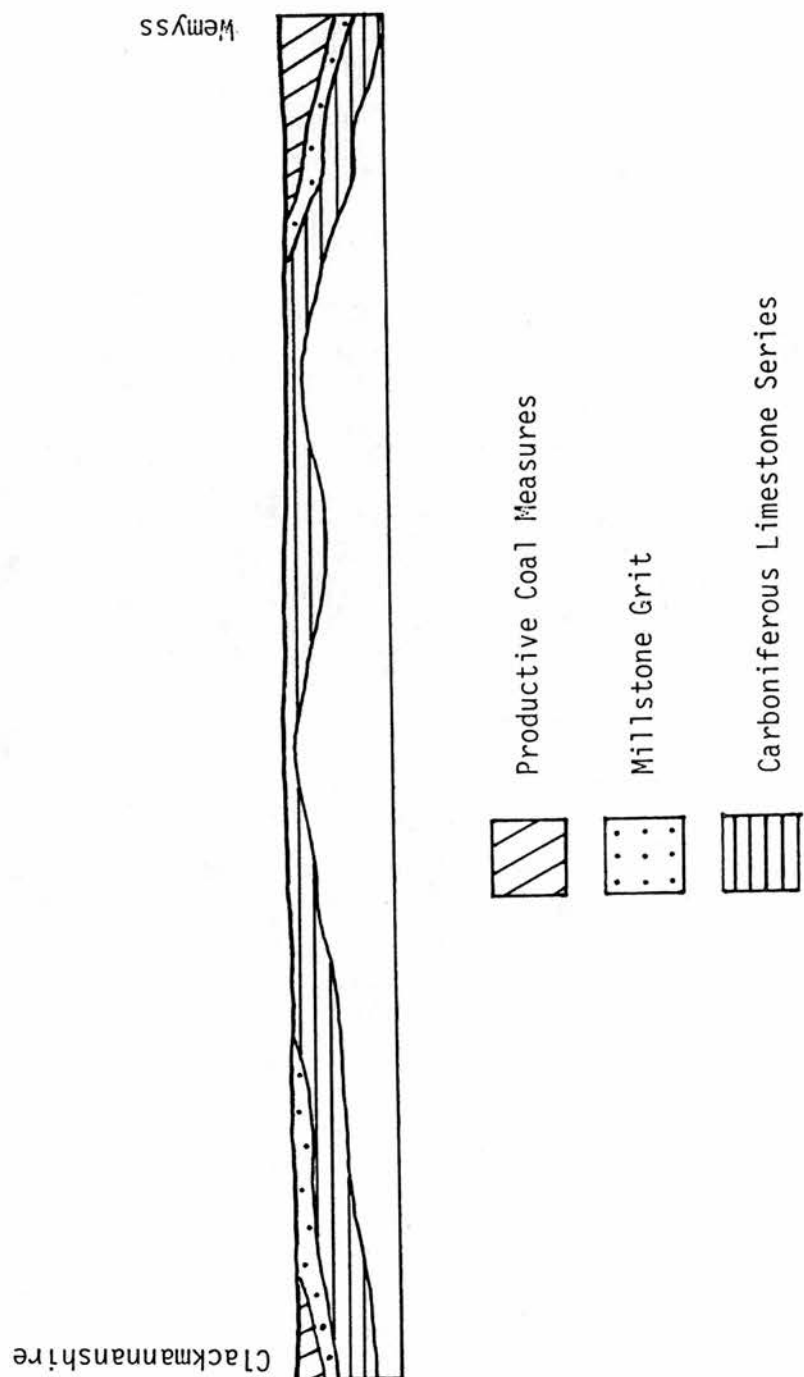
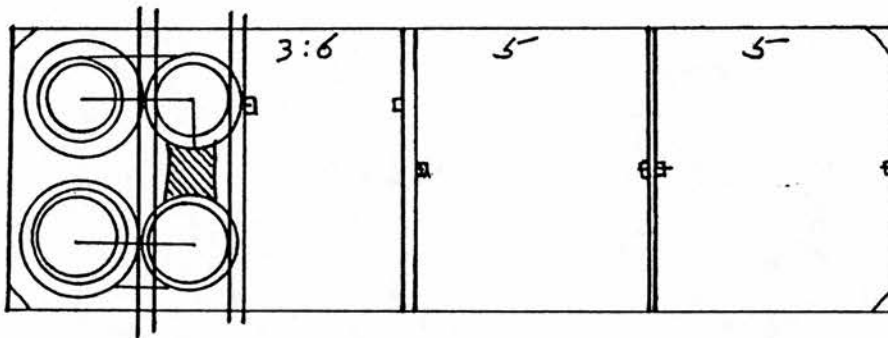


Figure 1.5 CADELL'S SKETCH FOR A SINKING AT WEMYSS (1849)



CHAPTER 2 - DAY-LEVEL DRAINAGE

In the developing technology of coal mining there are few areas showing greater ingenuity and enterprise than that of drainage. From the earliest crop pits to the great collieries of the twentieth century it was the drainage problem which provided the most significant and widespread challenge to the mining engineer. The simplest solution was to lower the water table by driving a drainage tunnel from a nearby low point up to the underside of coal seams in higher land. This day-level (so called because it drained by gravity to the open air or 'day') or 'adit' normally had its outlet in a river valley or, ideally, on the coast so that the coal could be drained 'level free' to the greatest possible depth. Fife was in a particularly favourable position for the employment of this technique, since many seams lay near the coast and were in demand for shipment. Also, several streams had cut deep valleys, known locally as 'dens', which invited the construction of day-levels. A good example is the Carden Den Burn which Bald describes as having 'given a great facility to the owners of the Dundonald Colliery to carry forward day-levels into several of the coals.....'¹.

The progression from an 'ingaun e'e' in a denside outcrop to a short day-level was a logical one which seventeenth and eighteenth century miners found hard to resist, and the further addition of a vertical pit provided a convenience of ventilation and access which set the seal on the success of day-level drainage. A typical arrangement is shown in figure 2.1, which is a cross-section of Dunfermline Colliery about 1794². By 1835, Landale was able to report that of 29 workable seams in East Fife, at least 16 were drained, in whole or in part, by day-levels³. It is now possible to identify 39

individual day-levels in the Fife coalfield, most of them dating from the eighteenth century. They are listed in Table 2.1 and their approximate locations are shown in figure 2.2.

At what date large scale drainage by day-level came to Fife is uncertain but it appears that in 1642 the Earl of Wemyss 'did dry by a mine' two seams at Lochhead⁴. Whether the Lochhead referred to is the one near Lochgelly or that near Coaltown of Wemyss remains unclear, but it is felt that the latter is the more likely. The New Statistical Account records the fact that day-levels were in operation in Alloa, Clackmannanshire, before 1650⁵ and a day-level was being planned in East Lothian as early as 1623⁶. It is possible, therefore, that the equally well developed Fife coalfield saw day-levels in use long before the Wemyss family adopted the method on a large scale in the mid 17th century. However, the Earls of Wemyss are known to have been pioneers in the scale of their mining developments and we shall see later that few coalmasters of the time could have afforded the capital outlay, so it seems reasonable to conclude that large scale drainage by day-level began in Fife on the Wemyss estates of the mid 17th century.

Clearly, the usefulness of a day-level was limited by local base level and engineers tried to provide an outlet as low as possible. For example, Sinclair emphasises that 'care must be taken, to take the lowest part for the mouth of the level, that the field can afford...'⁷. The lowest possible base level was low water on the Forth estuary, and Gemmell quotes at length a description of Earl David's low-water sluice at Barncraig, designed to protect the level at high water, but to allow the mine to drain at low tide. This was built about 1670 and was something of a novelty at the time. In David's opinion:

'...the like is not in Scotland or ever seen before in the world (that I hear of) and it is the surest fashion of any sluice to keep⁸ out water either of coal or other occasions.....'

Another low-water sluice was to be found at Blair Burn, a little to the West, where a man was in constant attendance to operate it.

The need to choose the outlet with care was emphasised by Clerk of Penicuik when he declared 'the right determination where to begin a level, is a matter of very great consequence',⁹ and he went on to illustrate the point with a calculation which shows how placing a level outlet a yard too high could lose from drainage 1500 cubic yards of coal. Consequently, topography must have to some extent conditioned the distribution of day-levels. However, figure 2.2 provides no clear-cut classification of levels by topography and it appears that the immediate surroundings of a day-level have been more important than any regional slope. Despite this, tentative groupings may be identified on the coast in the Kirkcaldy-Wemyss area, on the Leven valley, and in the areas to the West and East of Dunfermline.

The limitations imposed by local base level and, ultimately, by low water on the Forth meant that the deeper mining of the late 18th century began to probe the limits of the day-level method and it is unlikely that any were dug after about 1790. Goodwin, referring to that part of the coalfield around Levenmouth, concludes that even with day-levels, few early pits could operate deeper than about 90 metres below the surface and that most pits averaged only 55 metres¹⁰. Higher land in the Western part of the coalfield allowed deeper level-free mining and the Fordell level, for example, was about 75 metres below the pithead. The levels West of Dunfermline drained the pits to about 90 metres, but the Wallsend Pit, sunk in slightly lower ground, was level-free to only 74 metres.

In this respect the Kilmux level provides an interesting problem. Dron tells us that it drained the workings to a depth of just over 100 metres¹¹, while the New Statistical Account puts the length at 630 metres¹². Even if we adopt the assumption that the level was perfectly horizontal (and an estimate based on all the available information suggests that it had a very low gradient), the figures given by Dron and the NSA would require an average gradient on the surface of about 1 in 6 over the 630 metres. Such a steep gradient is not to be found in the Kilmux area. Thus Dron must have over-estimated the depth, the NSA writer underestimated the length, or both. If Stephen's location of this day-level at NO 370048 to NO 370041¹³ is correct, then he implies a drainage depth of less than 47 metres - a far cry from Dron's 100. One possible solution to the problem is that if underground workings or natural drainage connected the day-level with pits situated on higher ground to the West (Wester Kilmux is about 190 metres above sea level), a level-free depth of about 100 metres might have been attained.

The earliest day-levels were much shallower than this, however, and appear to have resembled deep ditches, at least in part.

Sinclair remarks:

'....For there are to be found coals wasted in their crops only; for conveying the water whereof, they have made a conduit, or level, which hath been open to the surface, like a great ditch, some whereof have been ten or twelve fathom in their deepness.' 14

The Earl of Wemyss, also writing in the 17th century, implies that such opencast was simply how the day-level was begun:

'Work the mine first by an opencast till ye come to the brae where ye take on stone or rock on¹⁵ your head; then go in with your mine.....'

By 1740, the opencast method had been superseded by underground mines, but even in the early 19th century, Bald could still recommend

that the day-level 'at first will be executed as an opencast or ditch, securely laid with flag stones in the bottom, and built in the sides with sufficient stone walls',¹⁶ but this was only where the commencement of the level was in comparatively flat ground. In this aspect of their construction, it seems that Scottish day-levels were not very different from the adits found in the East Midlands of England about the same time.¹⁷

In driving a level, the question of gradient was vitally important, and was examined by Sinclair who explained that the level should be wrought without ascent or descent and indicated that this could be achieved by making sure that the water had as slow a current as possible. Sixty years later, Clerk of Penicuik advised the same technique, stating that the water in the level:

'...should never appear to have any current, otherways it gives a strong proof that the level is run up, the consequence of which will be that a good deal of the coalfield will be lost. Therefore as the coaliers phrase it, a mine ought to be run with dead smooth water, that being the best levelling engine they commonly make use of.'¹⁸

This advice appears not to have been heeded in Dalgety parish, where mining operations in the North were carried on 300 feet (91.4 metres) below the surface. The level was at a depth of about 250 feet (76.2 metres) and machinery was thus required to raise water from the workings a distance of 50 feet (15.2 metres). 'Had the level been carried duly horizontal', says the writer, 'the whole of the coal now drained by machinery would have been level free. And thus had due regard been paid at first to the drainage level, the expensive machinery now erected on the works would, in a great measure, have been unnecessary.'¹⁹

For any given length, a level with a gentle gradient will drain a greater depth of strata than will a steeply inclined level. Thus,

provided that due regard is paid to the nature of the coal seams, the gradient may be used as a rough guide to the cost-effectiveness of a level. For this reason, an attempt was made to calculate the gradients of some Fife levels. The known heights of outlets were used, together with the levels' known depth in the pits and their lengths. The results, however, were inconclusive. The gradients were found to range from virtually level (Kilmux) to 1 in 70 (Rosebank) but with so many unknown quantities involved, such estimates could be nothing more than educated guesses. Although we know that 18th century day-levels near Liège were expected to have gradients of only 1 in 700, the very varied conditions in Fife do not permit a similar generalisation for this coalfield.

In some cases, conditions were such that a syphon arrangement was employed. This option was known to Sinclair²⁰, and described by Bald as a 'drowned level' or 'inverted syphon'²¹. The Mill Sink at Wemyss shore was such an inverted syphon sunk to 20 fathoms (36.6 metres) by a horse-driven mill in the mid 1650s. The coal was worked inland until the workings were as high as the pit head, when pumping ceased and water allowed to overflow at the sink mouth. A (probably different) syphon arrangement was still to be found at Wemyss in 1845 when a quarterly report from Henry Cadell points out that the drainage problem had increased because the syphon which drained the dip workings no longer vented the water²². About 1837, a syphon with a 2½ inch pipe was partly draining Chapel limestone quarry, near Kirkcaldy, the other method employed there being a windmill of two horse-power²³.

The actual dimensions of Fife day-levels do not appear to have merited much comment from contemporary reporters, except as general recommendations. Clerk, for instance, recommended levels 5½ feet

high (1.7 metres) by $2\frac{1}{2}$ feet broad (0.8 metres)²⁴, not 2 feet (0.6 metres) broad as quoted by Duckham²⁵, but nearly a century later, Bald was of the opinion that this sort of size was too small:

'Many of the levels of the present day are only 3 feet in width, and four and a half in height. Although these dimensions are in general sufficient to carry off the water which may be found in the colliery, they are too small when the mine is to be repaired, or when sediment or obstructions gather in them. They ought not to be less than 4 feet wide, by 5 feet 6 inches or 6 feet high.'²⁶

We know that Bald was familiar with many of the Fife collieries, so his comment would imply that the Fife levels were generally of the dimensions suggested by Clerk in 1740. For an example, we may turn to a drainage tunnel under the Kingsmuir, built to 'convey the water from the links' and being only 18 inches (0.4 metres) wide by $3\frac{1}{2}$ feet (1.1 metres) high, although it was over 300 fathoms (548.6 metres) long. Admittedly, this is not a colliery day-level, but we have no reason to suppose that its dimensions would have been significantly different had colliery drainage been its function.²⁷ For archaeological evidence, we have the modest outlet of the Urquhart level (figure 2.3), which illustrates how difficult it must have been to maintain a clear channel through day-levels of comparatively small dimension.

The maintenance problem would be all the greater in a long day-level, and Clerk believed that it would rarely pay to drive a level more than 500 fathoms (914.4 metres)²⁸. Despite this, the mean length of day-levels in Fife is nearly 2 Km (see Table 2.1). The estimated total length of 75 Km represents a considerable investment in terms of time and money, and individual day-levels could be very long. For example, the Fordell level, with branches, totalled some 8.8 Km, roughly matching a level of about 8 Km driven in stages between 1703 and 1774 on the Derbyshire-Nottinghamshire border²⁹. In this

correspondence it is tempting to look for some economic limit of day-level distance, but we cannot be certain that we are comparing like with like since the economics of a level would depend on construction and maintenance costs as well as on the nature of the seams which it drained. For example, the Balbirnie coal was worked for the forty years up to 1780 using only day-level drainage and produced in that time 365,000 tons of coal³⁰. On the other hand, the coal at Kilbrackmont was all worked out using horse-gin drainage before the day-level could be completed³¹. Despite such variety, the facility for carrying levels over long distances meant that an adit could provide a worthwhile return by draining workings over a wide area. For instance, a lengthy correspondence was carried on between Sir Robert Henderson of Fordell and his neighbours, Mr Wemyss and Lord Moray, with a view to extending the Fordell level so that it could drain the coal works of these latter gentlemen³². The negotiations continued over the five years from 1768 but were unsuccessful. The high value placed on obtaining level-free workings is shown by the fact that a consideration of 1500 guineas was discussed, to be paid to Sir Robert in three instalments. Maintenance costs could not have been negligible, for the method of allocating these among the proprietors also features in the correspondence.

Even as late as 1820, the utility of day-level drainage at Fordell is emphasised by Bald's recommendation to sink a new ventilation shaft so that the day-level could be 'carried forward vigorously night and day'³³, and in 1810 it was obviously important for the success of the Dunfermline Colliery lease of Eastfield to the Hallbeath Company that the tenants be allowed to communicate their levels as far as their new workings. However, care had to be taken to see that the levels were made so as not to injure the coalfield³⁴.

Sometimes, however, the extending of levels was forbidden, as in 1765, when a contract for the communication of the Urquhart level expressly prohibited the Wellwoods from taking the level any further than their own workings in Middle Baldrige³⁵. Similarly, the Balmule lease current in 1812 specified that the Pitfirrane level should not be communicated to adjoining properties without the special permission of the proprietor, a form of control to be expected in an area heavily dependent on day-level drainage³⁶. A proprietor would wish to protect his investment by restricting to his own property the advantageous level-free working, unless he was paid for the facility. We have already referred to the Fordell negotiations in this context, but might also mention the Pitfirrane level, which was said to have been made available for Lord Elgin's coalworks only on payment of substantial sums³⁷.

Although neighbouring landowners were very keen to obtain the use of an effective day-level, connection through another's property also had its drawbacks. In 1854, for example, the Laird of Balcormo tried to frustrate new workings at Kellie by plugging the day-level in his own property. He succeeded in depriving the Kellie workings of only 3 fathoms (5.5 metres) of level, the water finding an outlet up-level of the plug³⁸. Duckham has referred to the litigation which was stimulated by this sort of problem³⁹, but such difficulties could not outweigh the advantages of co-operating to provide level-free workings over several properties. These advantages must have been considerable.

Sophisticated drainage systems such as that at Fordell, or West Dunfermline (see figure 2.4), were built according to principles outlined by Clerk in 1740 and Bald in 1830, and these principles fall into four categories: First, the route of the level; second, the

actual driving of the adit; third, support for the roof; fourth, ventilation of the level.

We have seen that the day-level should be as near horizontal as possible and that the standard method of achieving this was to use the water as a guide. Clerk also recommended that the level be carried as straight as possible to the coal, using a compass for this purpose, otherwise 'the miners will be apt to make many serpentine turns, and goe as far out of the way, as a traveller may doe in a dark night',⁴⁰. He later points out that iron tools had to be kept away from the compass when readings were taken in case they had influence on the needle. Bald, too, recommends a straight line⁴¹. Obviously, this would reach the seams in the shortest distance, thus reducing construction and maintenance costs.

However, many day-levels were anything but straight. This may be due to local geological difficulties or to the fact that they were extended at different times to drain additional workings. The Pitfirrane, Urquhart and Balmule levels are good examples.

The actual driving of a day-level was made much easier with the introduction of blasting with gunpowder, which seems to have been in general use by about 1740⁴² and may account for the fact that although a Wemyss level in 1672 progressed at some 120 yards (109.7 metres) per annum, Bald could reckon on 700 yards (640 metres) per annum by 1823⁴³. Nevertheless, about 1765 the Urquhart level employed boreholes to carry the water through a band of hard rock instead of going to the expense of driving the adit across it. The contract of that date agrees that should a full size passage become necessary, it should be driven at the joint expense of both parties⁴⁴. On the other hand, hard strata may have compensated for the difficulty of driving by providing a sound roof which needed no support. It was Clerk's custom, for

example, 'to make a solid arch of stone and lyme, where I thought the solidity of the roof was in any way to be doubted'⁴⁵, and Bald recognised the need for timber supports, temporary if possible, or built so as to allow walls and roof arch to be erected within them. He thought that when the strata was not too soft, the roof could be strengthened by cutting it in an arched form⁴⁶. Contemporary reports of the Fife day-levels make little mention of roof supports, which tends to confirm our earlier view that these adits were not usually of large dimensions. However, near Balbirnie in 1814, part of a cross-cut mine connecting with a day-level was 'secured by props, stone buildings in the sides, and timberage above.'⁴⁷, while four years later at Urquhart, the security of the level was assured by stone buildings in several places⁴⁸. On the whole, though, these appear to be exceptions. The rule was for narrow adits, which made roof supports unnecessary.

As the driving of the day-level proceeded, ventilation became more of a problem and one solution was to employ wooden pipes, about 8 inches to 1 foot (20 - 30 cm) square, carried in from the day-level mouth to the forehead. Eventually, however, an air pit would have to be sunk to the level, a fact recognised by the Earl of Wemyss as early as 1662 when he recommended that ventilation shafts be sunk as often as they were needed⁴⁹. Water in the ventilation pits could be drained by boring down to the level, and if the bore-holes were found to provide sufficient air, the sink need not be completed. Air pits were also suggested by Clerk in 1740, although he also refers to the technique of pumping air 'to any length'⁵⁰.

There is ample evidence that in Fife, adit ventilation was by air pits, and the course of a level may sometimes be traced by a line of these on the surface (see figure 2.4). For example, the Pitferrane,

Urquhart, Halbeath, Fordell, Kelty and Lochgelly (a) levels all show evidence of this, and Goodwin has remarked on this as a feature of the coalfield further East⁵¹.

These pits not only provided air, but also allowed easy access for driving the level and for maintenance during its working life, and had this been appreciated by Sinclair, he might have been more inclined to recognise their value to the colliery. As it was, 'their only use being to communicate fresh air to the work-men', he felt this could be accomplished more cheaply by other means⁵². However, he does agree with Clerk and Bald that the shafts should not be sunk directly on top of the level, but should be offset to the side to prevent any falling rubbish from blocking it up. While Sinclair specifies no offset distance, Clerk recommends an offset of 1 fathom (1.8 metres) and Bald describes the practice as being to sink shafts 8 or 10 yards (9.1 metres) from the side of the level and connect them by a side mine⁵³. He recommends that ventilation shafts should generally not exceed 7 feet (2.1 metres) in diameter and ought always to be circular. Despite this, he had proposed 10 years previously that a new ventilation shaft at Fordell be 8 feet in diameter⁵⁴. This width was such that if any valuable coals were found in the vicinity they could be drawn by it. Since he envisaged a long life for this pit, he advised that it be 'craddled' with stones in place of wood. Elsewhere in the same report, he recommends widening and deepening the access pit then in operation, so it could be used for drawing coals and pumping water. Bald reinforces this multi-purpose view of air pits in a report on Urquhart coal where he states that the shafts must remain open for air and for access to repair the level⁵⁵. The top of one of the Urquhart air pits is shown in figure 2.5. The importance of easy access for repairs continued well into the late 19th

century, since levels often carried on performing a significant drainage function by being able to lessen the engine lift, sometimes very considerably.

The beneficial combination of day-level and pumping engine was recognised in the 17th century, and Nef points out that many systems of that period included an adit as well as more than one type of engine⁵⁶. In Fife there are several cases which provide evidence of such an arrangement.

After about 1780, for example, the Balbirnie level was able to lessen the engine lift by about 9 metres, while in 1818, Bald briefly considered a combined day-level/pump system for Townhill colliery, although he decided that even if the old day-level were to be cleared up, the engine fitted would still be insufficiently powerful to raise the water to that height. Instead of a possible deep winning of the Splint coal, he advised extending the day-level since there were still workable coals which could thus be laid dry⁵⁷. About 5 years later, at Lochgelly, it is reported that water had been raised from under-dip workings and poured into the day-level, a task accomplished by 'hand leverage'⁵⁸. At Fordell in 1831, however, we find the full power of a beam engine working at the Venerable pit to pump water from the Dunfermline Splint seam at 88 metres to the day-level at 45. Further East in 1856, we find that the availability of an old day-level at Wemyss encouraged John Williamson, the engineer, to be optimistic about an extension of the Parrot coal workings since water from the pumps could be delivered into old wastes and find its way out by the day-level. Given this advantage, he thought an engine of only moderate power would be sufficient⁵⁹.

Thus in Fife we find considerable support for Duckham's view that raising water only to the height of an adit saved a considerable

input of energy, and kept many day-levels in use long after they could have been superseded by powerful steam engines. In this respect, they must have been cost-effective, and may to a certain extent have delayed the innovation of the more powerful types of pumping engines.

In looking at the costs of day-level drainage, we may identify three aspects which are relevant to its use instead of, or together with, other drainage techniques. They are, first, the capital cost of construction, second, the cost of keeping the level in good repair, and third, how these expenses compare with the costs of installing and running pumping machinery.

The capital cost of a day-level would vary with several factors, particularly its length, cross-sectional area, amount of roof support, and depth below surface. This last factor is important because expensive air pits had to be sunk as the work proceeded. Stephen has estimated the cost of driving the Pitfirrane level in the 1770s as £3,000 per mile (1.6 Km)⁶⁰, taking no account of the cost of ventilation shafts, and he feels that this is of the same order of magnitude as Renwick's estimate for workmanship and timber at Belliston in 1790, where a figure of about £1,000 per mile (1.6 Km) was proposed⁶¹. This amount is confirmed by Green's proposal for Balgonie in 1785, where a figure of about £1,100 per mile (1.6 Km) may be deduced from figures given. However, we cannot be sure that Green is proposing an ordinary day-level, since Beaumont, commenting on Green's ideas, thinks this level should be 4 feet wide (1.2 metres) by 4 feet high (1.2 metres)⁶². The cost of driving the Fordell level, on the other hand, is put by Inglis and Inglis at £30-40,000⁶³. Whether this is in pounds Scots or Sterling is not clear, and neither is it entirely clear the length to which this amount refers. However, if we make the not unreasonable assumption that the figure is in pounds Scots, a Sterling equivalent of

some £4,000 - £5,000 would result. This amount may have included several air pits and probably refers to a level extending some 2 miles (3.2 Km), so a final sum of £2,000 - £2,500 per mile (1.6 Km) may be estimated. Stephen's 'order of magnitude' seems to be about right.

Further confirmation arises from a proposal of 1823 for a day-level to drain limestone on the Grange estate, near Burntisland. A figure of 'at least £1,500, perhaps considerably more, including contingencies' was estimated for a distance which appears to have been a little way short of a mile⁶⁴. There is no reason to suppose that costs would be very different were the level for draining coal instead of limestone.

Of these figures, the most reliable appear to be Renwick's of 1790 and Bald's of 1823. Given that Renwick's amount was for workmanship and timber, while Bald's seems all-inclusive, even allowing for contingencies, it seems reasonable to adopt the latter's figure as a basis for calculating the total investment in Fife day-levels. Thus at roughly £1,500 per mile (1.6 Km), the total investment in 46.8 miles (75 Km) would have been £70,200 by the end of the 18th century. This is considerably more than Stephen's highest estimate of £51,000⁶⁵, but his calculations were based on a total length of 17 miles (27.4 Km) which he felt would represent well over half the Fife total. It will be clear from Table 2.1 that this was a substantial underestimate, and more than counteracted the overestimation produced by using the Pitfirrane figure for cost.

Unfortunately, Stephen does not explain how his estimate of total length is derived. The method adopted for Table 2.1 was as follows: the length of 23 day-levels is known with some certainty, the mean being 2113 yards (1931 metres). It was assumed that the 16 day-levels of

unknown length would probably have a similar mean and thus total some 33,808 yards (30,896 metres). Adding this estimated total for 16 levels to the known total for 23, we arrive at a grand estimated total of 46.8 miles (75 Km). While it is thought unlikely that many long day-levels have been omitted from this calculation, it may be wise to regard the estimated investment figure as being, if anything, on the low side.

The second aspect of day-level costs arises from the expense of maintenance, which could sometimes be heavy. At Bo'ness, West Lothian, these charges had 'eaten up the whole free rent and commoditie of theheugh'⁶⁶. In Fife, however, it was recognised that such expenditure was a necessary feature of colliery finances, as at Balbirnie in 1814, where it was

'...most proper that this level be well looked after, and that frequently... If anything was to go materially wrong with the level to the West, it would prevent the working of Pitcairne coal'⁶⁷

Sometimes, recognition took the form of a formal agreement regarding maintenance costs. We have already noted the appearance of this topic in the Fordell correspondence of 1768-1773, but it also appears in the Urquhart contract of 1765, where the clearing and upholding of the level was to be charged equally between the parties⁶⁸.

The third, and perhaps more subtle, aspect of day-level costs is the question of how levels compare with pumping machinery. According to Nef, adits were generally dearer to construct but cheaper to run than an engine⁶⁹. However, Duckham estimates a conservative figure of £1,300 per engine, including pumps and engine house⁷⁰. If an average Fife day-level cost little more than £1,500 in the late 18th century, the level of capital investment seems not so very different. However, 18th century pumping machinery of all kinds

was less than reliable, and Clerk's view was that:

'A coal seam being discovered, the next thing to be considered, is, how to procure a level to it, for few coal seams will bear the expence of engines to draw the water from them, except such as are above four feet in thickness, and in a country where any quantity of coal may be sold.'⁷¹

This expression of the relative economy of the day-level is echoed in Bald's NSA entry for Alloa, Clackmannanshire. Here, referring to a powerful hydraulic engine (water wheel), he remarks that 'this method of draining a colliery is nearly as economical as that of a day-level'⁷². A similar point is made in a report on Dunfermline (Townhill) Colliery in 1825. In this case it was felt that no winning of the remaining splint coal should be made by steam machinery 'as no reasonable calculation can shew a return for the capital invested', and an extension of the Pitferrane level was stated to be the least expensive method of draining the coal⁷³.

Not far away, at Balmule, we find an indirect way of comparing costs. In 1812 it was estimated that, if wrought by the level, the proprietor might command one-eighth of the gross product in royalties. If drained by a steam engine, he might obtain only one-tenth. It seems that the difference was due to the extra expense for the tenant in installing and running an engine, but we must remember that the comparison is with a day-level already constructed. It is stated that were the Pitferrane level to be extended to Balmule, royalty would also be only one-tenth, so the implication is that steam and day-level costs were comparable for new installations⁷⁴. We have already suggested that this was the case. On the other hand, coals which were level-free were considerably more valuable than those which needed pumping machinery, with a royalty of one-fifth or one-sixth for the former compared with one-sixth to one-tenth when drained by a steam engine⁷⁵.

This difference can only be attributed to different running costs for the two drainage methods.

Given, then, that day-levels were comparatively cheap, it is not surprising that their use was maintained well into the 19th century, particularly when allied with powerful pumping machinery. However, the need to exploit deeper seams led to the redundancy of most day-levels, and the next two chapters examine the innovation process of the pumping machinery which at first complemented and later superseded them.

TABLE 2.1 - DAY-LEVELS IN FIFE

NAME	DATE BUILT	LENGTH IN YARDS (METRES)	APPROX LOCATION OF OUTLET
1. Rosebank	before 1794	1170 (1065)	NT 077886
2. Balmule	before 1812	1030 (937)	NT 075884 *
3. Pitferrane	1773	7620 (6934)	NT 068857
4. Urquhart	before 1765	2124 (1932)	NT 081868
5. Townhill/Buckieburn	before 1785	2112 (1921)	NT 121887
6. Townhill/Cairncubie		440 (400)	NT 099898
7. Whitefield/Cagiehall	before 1794	1760 (1602)	
8. Halbeath	before 1785	1760 (1602)	NT 122884
9. Lethans	before 1811		NT 055947
10. Kelty/Blairadam	before 1772		NT 125949
11. Kelty		1170 (1065)	NT 148956
12. Fordell	before 1768	9700 (8827)	NT 148852
13. Lochgelly (a)	before 1823		NT 187950
14. Lochgelly (b)	before 1823		
15. Kirkcaldy	before 1818	2200 (2002)	NT 285920
16. Dysart	1749	4400 (4004)	NT 302928
17. Blair Burn	1657		NT 316943
18. Barncraig (a)	before 1670		NT 330950
19. Barncraig (b)	1670		NT 330950
20. Cadham	1740	810 (737)	NO 278018
21. Balbirnie (West)	before 1794	1540 (1401)	NO 281018 *
22. Balbirnie (East)	before 1794	730 (664)	NO 282018
23. Balbirnie	1740	880 (801)	NO 289014
24. Balgonie	before 1731		NO 308008
25. Wemyss (a)	1672	1216 (1107)	
26. Wemyss (b)	1756 - 1786		NT 325946

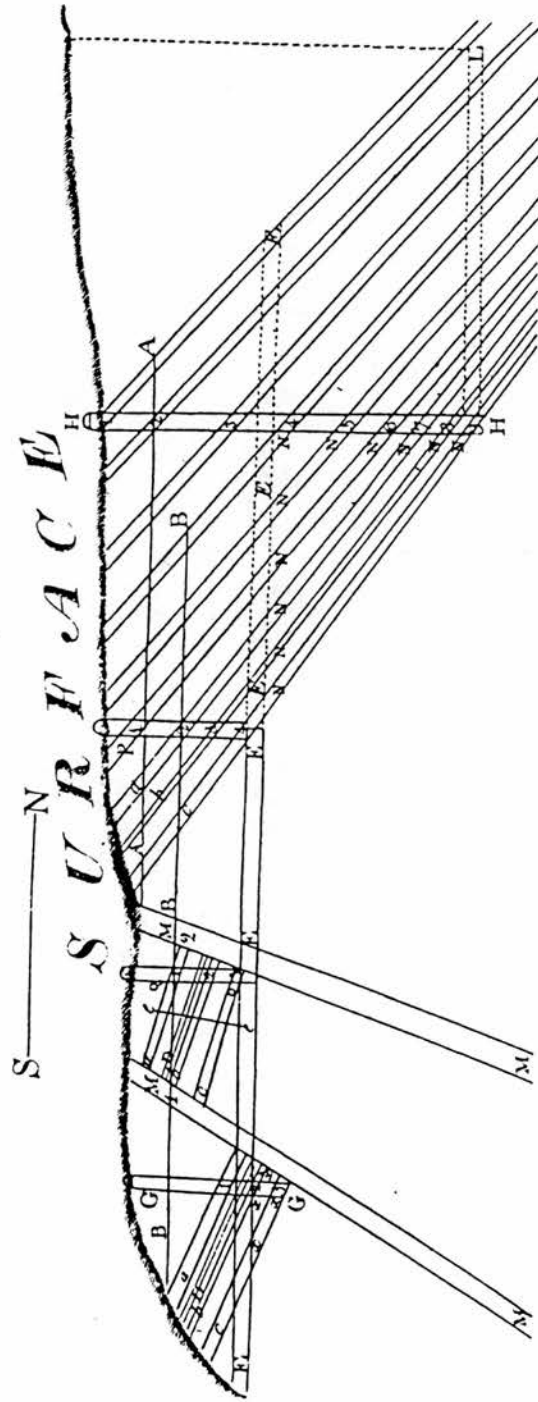
TABLE 2.1 - Continued

NAME	DATE BUILT	LENGTH IN YARDS (METRES)	APPROX LOCATION OF OUTLET
27. Wemyss (c)	1642		
28. Kilmux	1788	700 (637)	NO 370041
29. Pittenweem	before 1771	800 (728)	
30. Torry	before 1835		
31. Blairhall	before 1815		NT 999878
32. Tolbooth	before 1814		
33. Muir	before 1768		
34. Dundonald (upper)	before 1825	440 (400)	NT 227938
35. Dundonald (lower)	before 1825	440 (400)	NT 227938
36. Kilbrackmont	before 1837		
37. Belliston	before 1790		
38. Kellie	before 1766	2640 (2402)	NO 520030
39. Largoward	before 1792	3540 (3236)	
Mean of 23 known lengths		2113 (1931)	
Estimated total length of 39 levels		46.8 miles (75 km)	

* - discharges into another level



Figure 2.1 SECTION OF THE DUNFERMLINE COALFIELD (1794)



E...E...E represents the Pitfirrane level, showing a possible extension to the North.

Figure 2.2 DAY-LEVELS IN FIFE

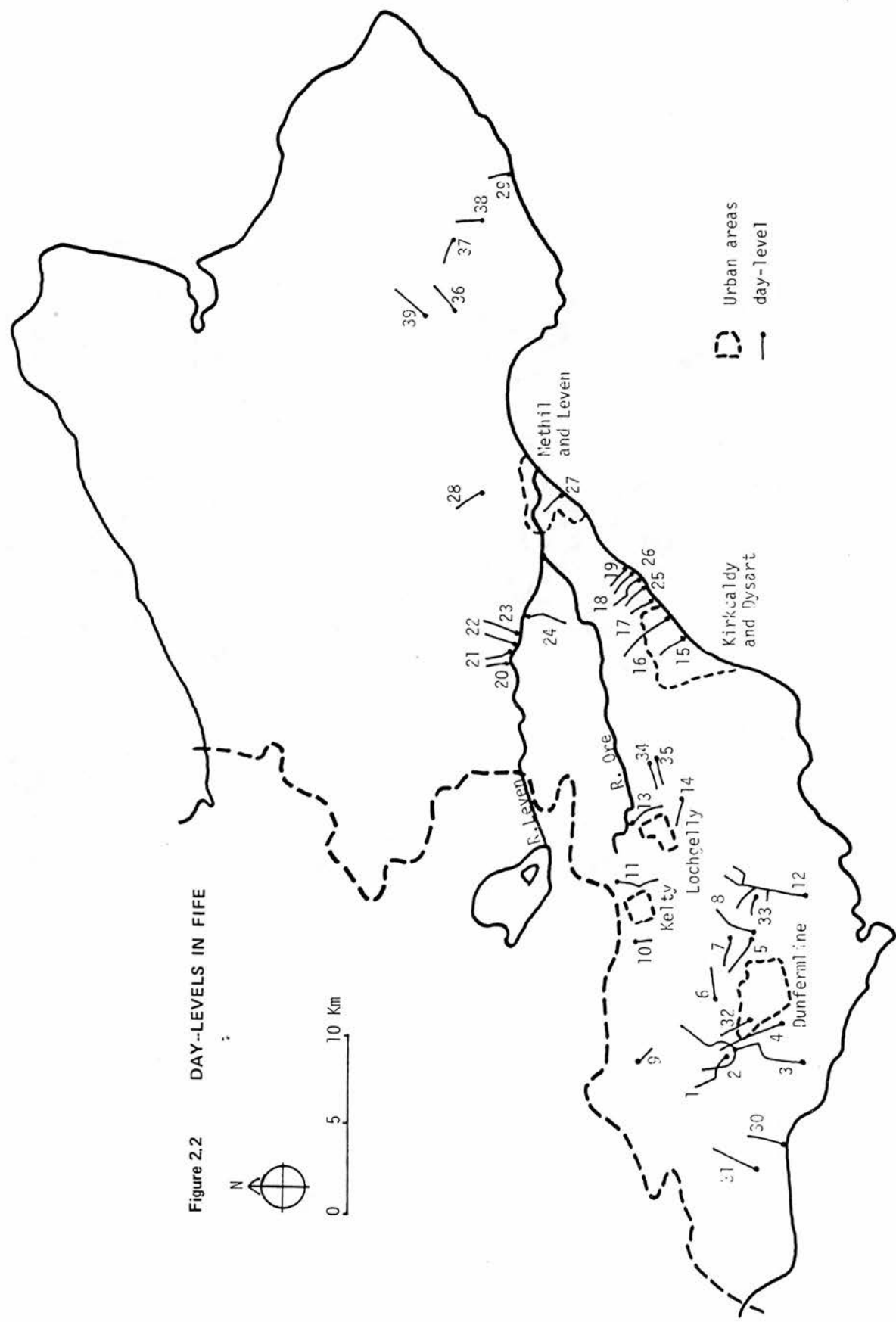


Figure 2.3

URQUHART DAY-LEVEL OUTLET

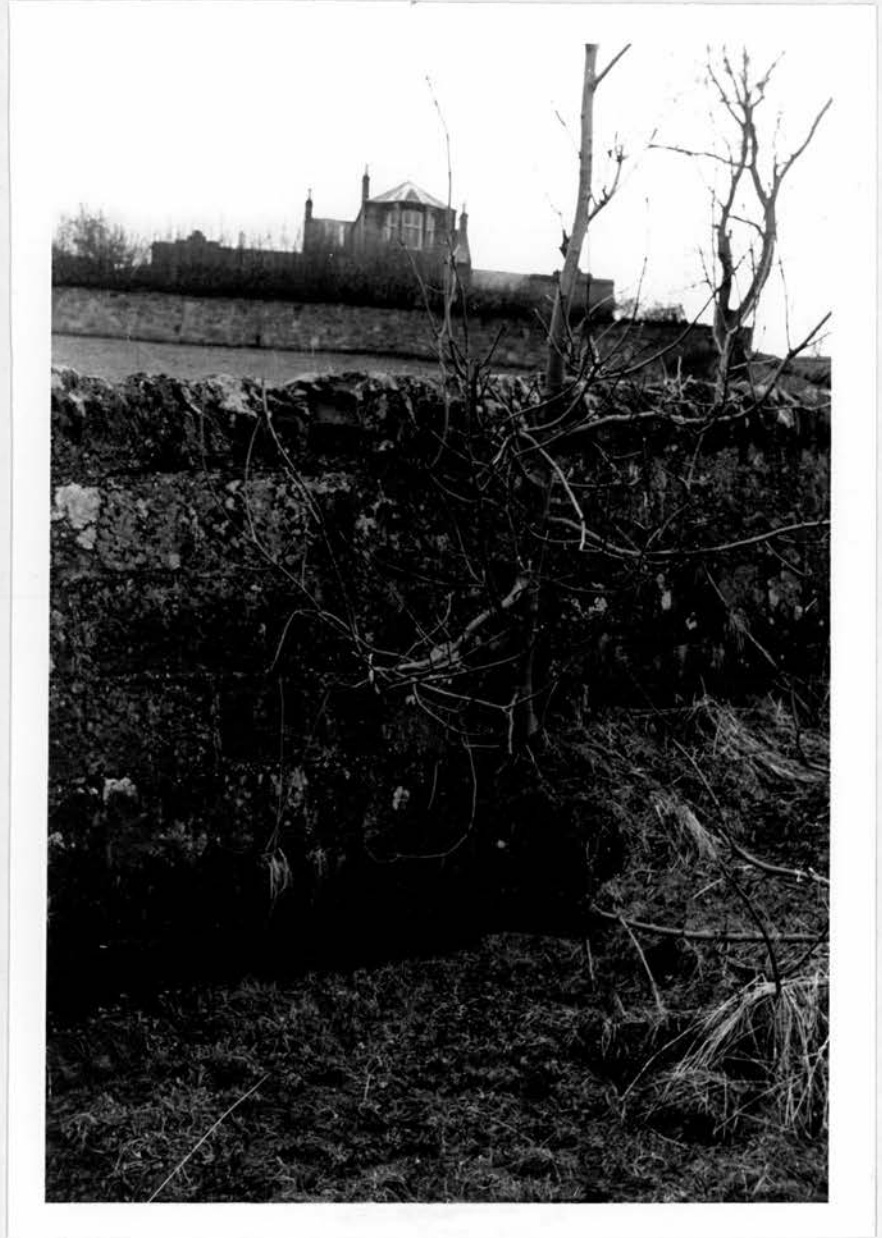
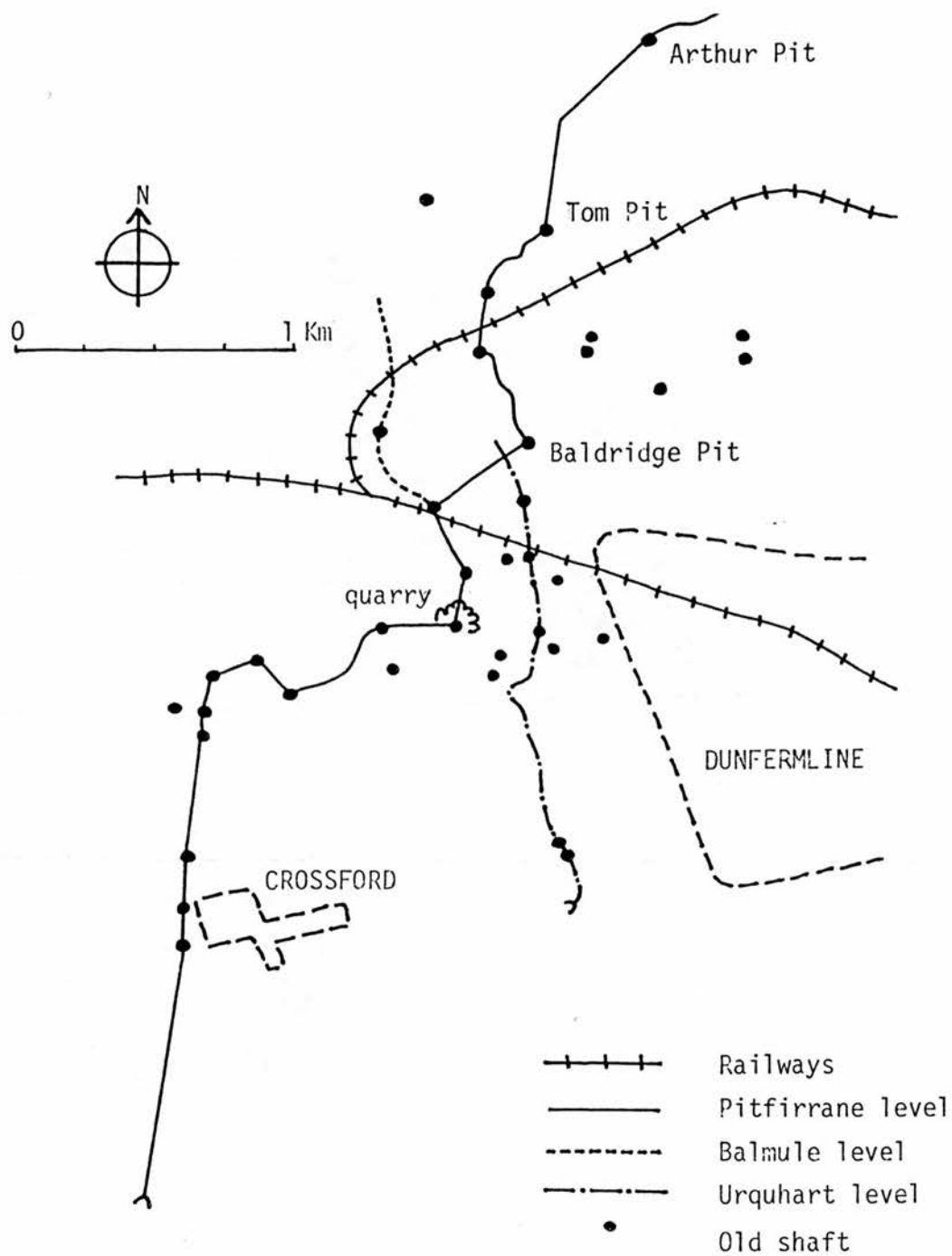


Figure 2.4 DAY-LEVELS IN WEST DUNFERMLINE



Rosebank level is omitted due to uncertainty about its exact course, but is thought to run South-easterly to an outlet just West of Baldrige Pit.

Figure 2.5 VENTILATION SHAFT ON URQUHART DAY--LEVEL



CHAPTER 3 - NON-STEAM DRAINAGE ENGINES

HAND POWER

Human labour was perhaps the least sophisticated power source for drainage machinery, but there is evidence of its use in Fife over about two centuries. The earliest application of manpower in this field did not actually involve machinery at all, but consisted of the 'Dam and Lave' method. From the pit bottom, a mine was run down in the coal and dams were placed across this at regular distances, each dam being 30 to 40 cm deep. The water was scooped or bailed ('laved') from one dam to the next until it reached the pit bottom or day-level. Although such a laborious method was suitable only for small-scale, comparatively dry workings, Bald implies that it was fairly common in what he calls 'the early periods of coal-mining'¹. For example, it may well have been employed at Wemyss some time before 1657, when old workings were discovered down to 2 fathoms (3.7 metres) under sea level².

The long-term survival of hand drainage was mainly due to the high cost of sinking pits and running day-levels. Once the level-free coal in a winning had been exhausted, new areas could be gained by driving a 'downset' mine from the pit bottom. Water raised from this downset had only to be brought by hand as far as the engine level or day-level, whence major pumping machinery or day-level could carry it off to the surface. Up to the mid 18th century, however, the water was commonly hauled to the surface by hand, since the hand windlass was very popular as a drainage engine. For an example, we may cite the case of Coalden in 1739, where the recommendation is made that:

"during the winter season the winlass men that draw the water begin about three in the morning, that the coal-hewers may enter at four or thereabout."³

If an overnight accumulation of water could be cleared in only one hour by the laborious process of winding it by the bucketful, then the pit could not have been particularly wet. However, the hand windlass was also used for winding coal, so found a ready application even when drainage was by other means. The ubiquity of the hand windlass is emphasised by Thomson who found it to be the one piece of machinery in use at nearly every pit and believes it to have been 'the single most important piece of machinery used'⁴. It was the adaption of this device for operation by horses which produced the versatile horse-gins of the mid 18th century, but when powered by human labour, it could only be used as a prime drainage engine in pits where water was not a major problem.

A much more efficient application of manpower was in the use of hand-driven pumps, and these were employed underground well into the 19th century. Originally, these pumps were used simply to shift water from one dam to another, effecting a considerable improvement on the 'dam and lave' method, but they later came to supersede it altogether, being laid all along the downset mine. In this way, water could be raised a considerable distance. The mechanism is succinctly described by Bald:

'...forcing pumps wrought by one or two men with a fly wheel and pinion, the shaft having two cranks which work two small reciprocating iron beams connected with the pump barrels. These machines have a spherical air vessel attached, in order to keep the water in constant flow, which is a great relief to the workmen, as they have not the vis inertiae to overcome every stroke or revolution of the fly-wheel'⁵.

At Fordell, for example, a report of 1817 records that sloping pumps drained a downset some 20 fathoms (36.6 metres) below the day-level, the pumps being wrought continuously by three shifts of people⁶. Various other references to hand pumps are likely to be, in fact, sloping pumps, and we find small downsets drained in this fashion as

late as the 1830s at Baldrige, 1840 at Wemyss and even 1850 at Lumphinnans. To find human labour still employed on this task in the burgeoning Fife coalfield of the mid 19th century is little short of astonishing, and our search for an explanation may be furthered by a closer look at the three examples noted.

First, at Lord Elgin's West Baldrige Colliery, a summons of damages dated May, 1840 claims that a hand pump had been used to pump water from neighbouring East Baldrige into the workings of the former⁷. In a memorandum written in reply, we are told that since the pump in question was only four inches (10 cm) in diameter and was driven by a boy, the amount of water transferred would only amount to 45 minutes pumping by Elgin's engine⁸. Even a low-powered steam engine would pump a considerable quantity of water in 45 minutes, which suggests that the effectiveness of hand pumping is perhaps not as limited as we might at first sight expect. Despite what Lord Elgin claims in his summons, the pump was installed primarily to drain a small area of coal thrown down some 4 fathoms (7.3 metres) by a dyke⁹. This water, having been pumped up to the West level, found its way eventually into Elgin's wastes.

In the Wemyss case, a group of downset workings in the BarnCraig coal were worked by hand pumps up to 1840¹⁰. However, it was then pointed out that a new winning of any extent would require steam power for both winding and pumping. Clearly, manual pumping could not be justifiably retained after 1840 in a seam like the BarnCraig, where the high quality of coal encouraged the introduction of a more capital intensive, but significantly more effective, method. It is nevertheless surprising that it could have been justifiable as late as 1840.

In the third case, at Lumphinnans in 1850, we find hand pumps employed in a downset working in which the water was lifted some 9 metres to the engine level¹¹. Workings above the levels had been exhausted and with the lease of the colliery soon to expire, a new sinking was out of the question. Nevertheless, it was recognised that the expensive hand pumping would have to be superseded, and in 1850 it was intended that the Gig (winding engine) should drain the downset.

These three cases illustrate some major characteristics of hand pumping in the 19th century. The method was used to drain comparatively small, downset workings by raising water a few fathoms to a level where other, more powerful engines or day-levels were available. It was phased out altogether by mid century, partly because of the fact that it could not operate effectively at depths greater than a few fathoms.

For example, the early 17th century workings found at Wemyss extended only some 2 fathoms (3.7 metres) below sea level giving a pumping height of perhaps 3 or 4 fathoms (5.5 - 7.3 metres). At Baldrige, the pumping height was also 4 fathoms (7.3 metres), while at Lumphinnans, 5 fathoms (9.1 metres) was the height attained. We find another example of hand pumping at Forthar Lime Quarry before 1814, where the required drainage depth was less than $2\frac{1}{2}$ fathoms (4.6 metres)¹². This example is worth quoting because although limestone may not be comparable with coal seams in terms of depth from the surface, hand pumping from coal was mainly utilised for downsets, and after the late 18th century was not required to perform the lift all the way to the surface. The greatest depth recorded for hand drainage in Fife mines is that in a Fordell report of 1817, when a downset of 20 fathoms (36.6 metres) was drained by the sloping pumps to which reference has

already been made. This maximum figure must throw some doubt on Boyd's assumption that a document of 1570 refers to hand pumps when it tells of shafts up to 60 fathoms (109.7 metres) deep¹³.

Even draining a shallow downset was an expensive business and this is one reason why more cost-effective methods had to be introduced. At Pitfirrane in 1777, for instance, Charles Beaumont complained that:

"we are forced to work at the heavy expence of pumps, as the number of dykes renders an engine of little service...."¹⁴

and we have already noted that the Lumphinnans downset was to have hand pumps replaced by the Gig about 1850. In this case, the replacement was due to the expense of hand pumping, but its limited effectiveness is also shown by the fact that the opportunity was to be taken to run the downset a few feet deeper and so win a greater amount of coal¹⁵.

The fact that hand pumping lasted as late as 1850 may be partly explained by the relatively low post-war wages of the early 19th century, but costs would also have been kept down by the employment of women and children prior to the legislation of 1842. This is illustrated by the following extract from the Report of the Children's Employment Commission, which identifies one group of workers as:

"PUMPERS - Girls and boys whose business it is to descend into the deepest part of the mines to pump rising water to the level of the engine-pump, in order to keep the men's rooms of work dry; they not unfrequently work up to their waists in water, or in such cramped situations as to be nearly covered; it is a severe and continuous process; they are relieved every six hours and rest twelve"¹⁶

In general, however, Bald was firmly against the sort of small downset workings which were typically drained by this kind of labour.

There are at least three Fife reports in which he refers to such workings as 'irregular', 'injurious' or 'contrary to the approved practice of collieries',¹⁷. The reasons for his antipathy appear to be twofold. First, the drowned wastes proved hazardous in later workings, especially since many early downsets were unmarked on any plan. Second, the presence of wasted areas could upset subsequent drainage schemes, for example by allowing water to accumulate in the dip workings instead of flowing out by a day-level¹⁸.

Despite Bald's disapproval, hand-powered drainage in Fife was viable and to some extent cost effective over a very long period. From the dam and lave technique of at least the early 17th century, through the hand windlass and the sloping pump to the downset workings of the mid 19th century, we find hand drainage making its contribution to the development of mining in Fife. For larger scale mining, however, other sources of energy were required and it is to these that we must now direct our attention.

HORSE POWER

The drainage machine which enjoyed probably the most widespread distribution in Fife was the horse-gin. It was easy and cheap to build, reliable in operation and reasonably effective in shallow seams, but its familiarity means that contemporary documents tend not to mention it, so an accurate picture of its distribution and significance is difficult to define.

Technically, it seems to have been a development of the common windlass using a wheel and pinion arrangement (see figures 3.1 and 3.2). This originally drove a chain and buckets as illustrated, but some gins operated pumps through a crank. The

most celebrated horse-gin in Fife was that set up by Sir George Bruce at Culross before 1590 in which three horses drove a chain of 36 buckets. Bowman believes this engine to have been the first of its kind in Scotland, and possibly in the United Kingdom.¹⁹

By about 1750 the horse-gin was in use for both drainage and winding at collieries throughout the County and this period probably marks the peak of its utilisation. The innovation of more powerful sources of energy in the late 18th century heralded a decline in the horse-powered drainage engine, although its use for winding carried on well into the mid 19th century.

In assessing horse-gins as a drainage technique we must first examine how an engine worked and what it looked like. Secondly, the effectiveness of the machine must be looked at, including the depth drained and the flexible nature of the system. This leads us to look at its comparative reliability and, fourthly, its costs. Finally, we may attempt an estimate of how many horse-gins remained operating by the end of the 18th century. In this way, we may be able to paint a picture which places the horse-gin in its proper perspective of technological development in Fife's mine drainage.

The machine itself was of simple construction, as will be seen from figures 3.1 and 3.2. A horse, or horses, was driven in a circular path while harnessed to a wooden beam (or 'brachium'). This turned a vertical axle on which was mounted a large cog-wheel. In figure 3.1 this meshes with a large wheel to drive a horizontal axle on which is mounted a chain and bucket pump. The gin in figure 3.2 is set up for winding but could easily wind buckets of water, drive a chain and buckets or, by replacing the winding drum

with a crank, could operate a column of pumps. This last arrangement was certainly in operation at Strathore about 1740, since a letter from Lord Elphinstone asks for the return to Bo'ness of a borrowed horse-gin 'with the cranks 3 brass pit barrells and pumps',²⁰.

The amount of leverage which the horses could exert would depend largely on the diameter of the driving circle, and Clerk of Penicuik recommended that the diameter be not less than 40 feet (12.2 metres) since 'in a circle of 20 foot, a horse will lose near a third of that force, which he could exert in a circle of 40 foot diameter',²¹. Smaller diameters appear to have sufficed for winding, however²². Apart from the diameter, another aspect of the driving circle which influenced efficiency was whether it encircled the pit mouth. Access to the pit would obviously be much easier where the design was as figure 3.1, rather than figure 3.2.

In general, horse-gins appear to have been worked by a small number of horses, the precise number depending on the work to be done and whether the colliery could afford the upkeep of the animals. Bruce's engine at Culross was worked by three horses²³ but in 1656, a horse-gin driving a chain and buckets at Blair Burn, Wemyss, was powered by no fewer than 8 animals at once²⁴. Also, an estimate of running costs for a horse-gin at Strathore, probably about 1738, allows for the upkeep of 6 horses²⁵. Although it is not stated how many were used at once, the fact that there were to be 3 ginsmen implies 3 shifts, with 2 horses per shift. At the start of the 18th century, the 'Compleat Collier' found the horse engine 'wrought with one or two horses at a time, as the water requires',²⁶ and this contemporary view is echoed by Atkinson who thinks that the one or two-horse gin was the commonest type²⁷, though in this case it seems the gins referred to are for winding. This is probably also true of

Duckham's remark that the one-horse gin was still to be found in East Scotland in the 1840s²⁸, and an example could be found at Clunie, where one horse was driven by a 12-year-old²⁹. What may be the latest evidence of a Fife horse-gin definitely being used for drainage is not actually at a colliery at all, but at Dalachy lime workings, near Aberdour in 1802³⁰.

The effective depth of horse-gin drainage provides us with some interesting data, since it appears that these machines, at least in Fife, reached depths far in excess of the 15 fathoms (27.4 metres) limit given for Alloa, Clackmannanshire³¹. Bruce's Culross engine, for example, drained workings to a depth of 40 fathoms (73.2 metres), while a horse-driven chain and buckets set up at West Wemyss in 1622 drained a seam some 20 fathoms (36.6 metres) under sea level. In 1708, we are told, a horse engine was used if a pit was sunk more than 30 fathoms (54.8 metres), apparently in preference to a hand windlass³². For the time, these depths represented a remarkable advance, but by the early 19th century they had been overtaken by other power sources. By 1808, for example, Bald could comment on the small depth attained by horse-gin drainage³³, a point to which he returned in his article for the 'Edinburgh Encyclopaedia' where he stated that drainage by horses meant that operations had been limited both in depth and extent³⁴. Landale reflects this last comment in his note on the Bwhouse seam, which he found had been 'wrought extensively by a day-level, and for some acres by a horse work, to 28 yards deep.'³⁵ This altered perception of depth shows the horse-gin as a significant improvement in mine drainage when it was introduced by Bruce and taken up by the Wemyss family, but eventually being seen as less satisfactory, ending the 18th century in use only at collieries where its low capital cost and flexibility could be allied with workings not too

demanding in terms of depth or extent.

The flexibility of the horse-gin was a considerable advantage at small collieries, and occurs in two respects. First, the gin could be moved from one place to another. Thus if workings became too deep or too widespread to work economically, the horse-gin could be shifted to a new winning nearby. It was even possible for one coalmaster to borrow a gin from another, as in the case at Strathore about 1739 when a cog and rung gin was borrowed from the Duke of Hamilton's works at Bo'ness and returned about four years later³⁶. The second respect in which the horse-gin was flexible was that it could be used for winding as well as for drainage. The two functions came very close together in cases where barrels or buckets of water were wound to the surface like loads of coal, but we have no evidence that this technique was widespread in Fife. Nevertheless, it is interesting to note that as late as 1843, water was drawn in buckets from the Victoria Pit, Wellwood, where the power was supplied by a steam engine installed originally for winding. As we might expect, drawing the water in this way was 'very troublesome' and could have been even more so were a horse-gin employed³⁷. The Whim or 'Scotch' gin, primarily a winding engine, could only perform drainage in this laborious fashion, but the cog and rung gin was suited to both winding and drainage, and when allied with its geographical mobility, this flexibility of function makes all the more difficult an enumeration of horse-gins employed in drainage.

In examining reliability, we are perhaps on slightly stronger ground.

The main advantage enjoyed by horse-gins in this respect was that the motive power could be guaranteed, unlike water and wind power. Also, the simplicity and ease of construction of the machine

would suggest that no highly specialised skill was required to effect any necessary repairs. On the other hand, the cog and rung gin was susceptible to broken teeth, and Clerk makes this point where he refers to the gins at Newcastle:

"I seldom observed any of them at that place, where the teeth or cogs were all entire and there was always a sudden jirk given, where any of these happened to be broken."³⁸

Other problems occurred, however. For instance, the gin borrowed for Strathore had a spindle 'insufficient when it came' and was thought to be not worth sending back³⁹. Also, the 'start' (not the spindle, as stated by Thomson) had broken only two days after the gin arrived, and had been used by one of Roth's tenants as a couple for his horse team. It is not entirely clear whether the man had used the broken one or, on the dismantling of the gin, had used the replacement which had been made. Probably the latter, since, if the part was required to be returned to Bo'ness, 'I shall cause make a new one'⁴⁰.

In keeping with the comparatively small scale and straightforward design of the horse-gin, the costs of installation were modest. For example, a 1785 estimate for Balgonie puts a horse-driven winding gin at £52. This is for a gin of 20 feet (6.1 metres) diameter with ropes to 30 fathoms (54.9 metres). A more powerful gin of 26 feet diameter (7.9 metres) having ropes to 50 fathoms (91.4 metres), not 40 as stated by Stephen, was to have cost £78⁴¹. Admittedly, these were whim gins for winding, not cog and rung gins for drainage, but the cost of a drainage gin could not have been very different. In fact, Donnachie and Stewart put the cost of an agricultural horse-mill at about £70 in 1797, and this for a machine which was probably more complex than a colliery gin⁴².

Despite the low capital outlay, running costs were fairly high in relation to the work output, and this expense is remarked upon by several writers⁴³. The actual amounts involved may be gauged from a computation of about 1740 in which there is a calculation of the running costs of a horse-gin compared with a windmill. Here, the cost of employing 6 horses and 3 ginsmen for one year is put at £1,300 Scots, compared with £480 Scots annual cost for a windmill⁴⁴.

To put these costs in their proper perspective, some assessment of numbers must be made. Lack of information makes this a hazardous exercise, and in order to clarify possible sources of error, what follows is an explanation of how our estimate was derived.

While a date earlier in the 18th century, probably around 1750, would give a larger number of horse-gins, the end of the century had to be selected. The main reason for this is that there is a large and comparatively reliable bank of data in the OSA (1790-1798) and in the series of reports by Robert Bald (1808-1825), which allows us to produce a more reliable estimate for that period than for any other time in the 18th century. Also, by 1800 other drainage techniques were becoming widely established, so horse-gins about that time may be readily compared with steam, wind and water power, as well as with day-levels.

The method adopted was to identify which Fife collieries were working about the year 1800 and then eliminate those which are known to have been drained by other means. Discounting hand drainage, the remainder must have been drained by horse-gin or were naturally level-free. The first source of error in this process is in identifying which collieries were in operation about 1800. At that time, 'colliery' referred to a group of pits rather than to the one large

pit of the late 19th century. Bearing this in mind, a total of 282 Fife collieries were listed, and 68 of these were identified as having been in operation around 1800. In some cases, a firm date was unobtainable, so it was decided that unless otherwise stated, a colliery working at the time of the OSA statement, or working at the time of a Bald report would be regarded as operational around 1800. The 68 collieries were then studied in turn, so that the drainage technique might be identified, and the results are given in Table 3.1. The 21 collieries which may have been drained by horse-gin are listed in Table 3.2.

This method of 'estimating by elimination' is obviously far from satisfactory. However, counting horse-gins more directly is virtually impossible. For example, Goodwin's 6 gin pits (not 7, as stated by Stephen) on the Eastern area of the Fife coalfield could refer to gins in operation at any time between the early 17th century and the early 19th⁴⁵. Even if we could be sure they were all horse-gins, some may well have been used for winding during part of their life. The 6 gin pits listed in the 'Catalogue of Plans of Abandoned Mines' are open to similar objections, so our process of elimination seems the only recourse⁴⁶. The resulting figure of 21 collieries drained by horse-gin is almost certainly an overestimate. As an example of the kind of problem encountered, we may take Burnturk Muir. In this case, the OSA tells us that in 1790, workings had not as yet gone far below the surface 'for want of proper contrivances to carry off the water'⁴⁷. Since a horse-gin would have been a 'proper contrivance', it seems there was none at that time. The tacksman was, however, 'seriously engaged in attempting to obviate those inconveniences which have hitherto impeded the working', but there is no evidence as to what technique was to be employed. It is

unlikely he was setting up one of the more noteworthy machines or digging a day-level, since there is no record of such. Possibly he was building a horse-gin. Despite the fact that these workings were mostly given up by 1845, the time of the NSA, a small amount of coal was still being produced at that time. It seems probable, therefore, that the colliery was working 'around 1800' and a horse-gin, that most unremarkable of drainage engines, was employed to keep it dry.

Our resulting 'overestimate' of 21 collieries may be compared with Stephen's figure of 40 horse-gins, which he describes as 'almost certainly a gross underestimate',⁴⁸. It is not entirely clear whether this figure is for horse-gins working about 1800 or having been working by 1800. Probably the latter. Unfortunately, he does not explain how the figure was derived.

The location of the 21 'horse-gin' collieries is shown on figure 3.3. They are widespread throughout the West of the coalfield but have a more concentrated distribution in the East, particularly in a group of 8 running North-East from Markinch. These were typical of the small landsale mines mentioned by Duckham, and were unfavourably situated for day-level or water-powered drainage⁴⁹.

In summary, we may see the horse-gin in Fife's mine drainage as being an early innovation and widespread in the first half of the 18th century, but in decline by the later part of that century when no more than a few collieries could have been drained by the method. The technique was suited to small-scale enterprises, where its relatively limited depth and high running costs were compensated for by a low capital investment and considerable flexibility. The horse was a reliable source of power and on the whole made a considerable contribution to the development of coal mine drainage in Fife.

WIND POWER

The windmill did not prove a conspicuous success as a drainage engine in Fife collieries. However, an examination of its rise, progress and decline may serve to illustrate some of the problems facing the mining entrepreneur and how solutions were sought in technological innovation. It is useful to begin with an overview of the windmills in Fife, including those erected for purposes other than mine drainage. We will then assess the efficiency and reliability of the windmill as a pumping engine, and finally, look at the costs of building and running a windmill, especially in comparison with other drainage techniques.

Of the 90 - 100 windmills in Scotland, there is a record of at least 19 in Fife, with plans for a 20th which was probably never erected. They are listed in Table 3.3 and their distribution is shown in figure 3.4. No fewer than 7 mills were definitely built as mine drainage engines, with another 4 which may have been. Their insignificance relative to day-levels is illustrated by the fact that of Landale's 16 seams drained by day-level, only one was partly drained by a windmill in an area extending only a few acres⁵⁰.

Windmills appear to have been introduced to Scotland from England and Holland, starting with one at Largo in the mid 15th century, but their use for mine drainage dates from the late 17th century and most references are from the 18th. Sinclair was well aware of the power which a windmill could apply to a chain and bucket pump but according to Bald, windmill application to mine drainage in Scotland came after 1708⁵¹. At that time, the only person in Scotland able to advise coalmasters was John Young. Young, a millwright, had been sent to Holland to study their windmill designs and 'windmills were accordingly erected upon several collieries'⁵². The limitations

of Scottish windmill expertise in the early 18th century are reflected in the proposals for the Strathore windmill, where the mason was to be directed by Mr Row (who Duckham thinks may have been an Englishman). The mason himself was to be the same man who had built Lord Stair's windmill in 1737. The two cranks for the mill were to be got from Newcastle and the pump barrels from London⁵³. On the other hand, it could be argued that Row was employed primarily for his mining expertise while the cranks and barrels were pump machinery, not mill parts. Nevertheless, as Donnachie and Stewart suggest:

"During the mid and late 18th century a large number of tower mills were erected in Scotland. It seems probable that the majority.....were constructed by local millwrights and masons....working on basic designs from the North of England"⁵⁴.

By 1740 it was clear to Clerk that a windmill would be powerful enough to drain any colliery of the period if it could go for 5 days a week, or perhaps even a shorter time. However, he also recognised its major defect, in that sometimes 'it is not serviceable by reason of want of wind, which one wou'd not readily suspect in a country like Scotland'⁵⁵. This opinion virtually summarises the accepted view of pumping windmills at Fife collieries. They were fairly effective, but unreliable, and thus could not compete with the more reliable water and horse-gins or with steam power.

Sinclair's view was that wind power was every bit as effective as water power, and if the wind failed to blow, horses could substitute. He refers to the power of a windmill in turning up to 7 pairs of mill stones at once, and also to its ability to raise and saw great tree trunks, which he claims could not be of greater weight than 10-12 fathoms (18.3-21.9 metres) of chain and buckets for drawing water⁵⁶. Eighteenth century windmills were able to drain greater depths than this, however, possibly due to the replacement of chain and bucket with the

more effective pumps. For example, the mill at Balgonie about 1740 raised water from 16 fathoms (29.2 metres) by means of 9-inch (23 cm) pumps⁵⁷. The planned windmill at Strathore was costed on the basis of a 30-fathom (54.9 metres) sink, although a contemporary sketch shows pumps for 20 fathoms (36.6 metres) (see figure 3.5) and the cost of sinking was to be based on 25 fathoms (45.7 metres)⁵⁸. There appears to be no foundation for Thomson's view that this sink was to be 22 fathoms (40.2 metres). In any case, it is clear that a windmill could easily drain a pit of up to 30 fathoms (54.9 metres) deep.

This sort of figure is confirmed in some correspondence of May, 1738. On the 10th, Lord Elphinstone, apparently acting as an adviser to Lord Rothes, wrote a memorandum which recommended a windmill to drain the Easter Strathore coals. Four days later, he wrote to Robert Ainslie at Stair asking for details of the mill there. Ainslie's reply gives the depth of Lord Stair's windmill pit as 20 fathoms (36.6 metres). We know that the Wemyss windmill pit was 27 fathoms (49.4 metres) deep, and that at Kellie was 20 fathoms (36.6 metres), so the depth of windmill pits appears to conform with what Duckham has called 'common' depths of 20-25 fathoms (36.6 - 45.7 metres) for 18th century Scottish collieries. Add to this the fact that the windmill described by Ainslie could:

"with a moderate galle of wind....draw 24 hours
off our watter in four hours time"⁵⁹.

and it may be concluded that the windmill was indeed strong enough to provide an effective motive power for Fife colliery drainage in the 18th century. Bald, however, describes them as 'powerful...but irregular' and we must now try to assess how much of a disadvantage was this irregularity⁶⁰.

In 1708 it was recognised that power for drainage should be available whenever it was required, and that in this respect, the wind was unsatisfactory⁶¹. To cope with this problem, two solutions have been proposed. First, Clerk recommended the making of underground reservoirs so that the water could be stored pending the windmill again being set in motion⁶². There is no firm evidence of this technique in Fife, except in connection with the Cluny water-gin⁶³. Second, stand-by appliances might be erected, such as that directed by Lord Wemyss in 1676 when he instructs that a 'horse-work' be set up as well as a 'wind-work'⁶⁴. It seems that he feared a broken pumping chain rather than calm weather, however. Clerk, too, recognised the value of a stand-by machine but he saw the assistance coming from a water-wheel 'under any extreme necessity'⁶⁵.

On the other hand, unreliability does not appear to have been a major cause of windmill closures in Fife. For example, the Dysart mill, dated by Donnachie and Stewart as late 17th century or early 18th was still being used for mine drainage in 1864⁶⁶. The Kinninmonth mill was damaged by a gale, and abandoned because the owner could not afford to replace it⁶⁷, and the Balgonie windmill was closed in 1743 because the colliery was undersold from nearby Balbirnie, where the seams were drained by day-level⁶⁸. Admittedly, the windmill draining Kellie coals was succeeded by a steam engine because 'the windmill could not drain it' but this may have been due to the quantity of water rather than unreliability of the source of power⁶⁹.

Furthermore, the relevant Rothes manuscripts concerning the proposed Strathore mill nowhere imply a significant lack of reliability. Indeed, Lord Elphinstone recommends it as the 'preferable engine',

mainly on grounds of cost, but with a suggestion of unreliability for the main alternative - a water gin⁷⁰. On the whole, the supposed unreliability of windmill power does not appear to have been a major disadvantage in the Fife coalfield, so perhaps we must look to the question of cost to explain why other drainage engines were more widely employed.

It is unfortunate that the drainage windmill for which we have most information, Easter Strathore, was probably never built. Accounts for July and August, 1738 show that workmen were paid for quarrying stones to build the windmill but no further record exists⁷¹.

Duckham sees Ainslie's letter of 20th May describing the mill at Stair as a description of the Strathore mill and supposes from this that the windmill was actually built, but it seems more reasonable to suppose that it wasn't. We are therefore deprived of any proper assessment of how successful the mill would have been. Nevertheless an examination of the proposals and estimates is instructive.

As we have seen, Lord Elphinstone recommended a windmill on 10 May 1738, and a few days later received from Ainslie a description of the mill belonging to Lord Stair. This mill had cost £152-0-5 in 1737, with a pit depth of 20 fathoms (36.6 metres)⁷². The first estimate for Wright's work on the Strathore mill was for £53-7-0, but what appears to be a slightly later figure, estimated by Stephen Row, is for £115-4-0⁷³. However, this figure is for a pit depth of 30 fathoms (54.9 metres), compared with the earlier 20 (36.6 metres). A third estimate, including materials and the sinking of a 25-fathom (45.7 metres) pit, produces a total of £308-5-0 which we may reasonably take as the total estimated cost of the windmill and sink⁷⁴. Since £50 is here allowed for sinking, the

figure accords perfectly well with Donnachie and Stewart's estimate of £2-300 for the erection of a late 18th century windmill⁷⁵. This compares favourably with £1500 for an average day-level or £1300 for a steam engine but is roughly the same capital cost as a water wheel and is much more expensive to build than a horse-gin. However, Elphinstone felt the Strathore mill would be cheaper than a water-gin both to build and to operate:

"Therefor the windmill seems to be the preferable engine, seeing it is believed it can be erected at a much less expence than the Bob Gin, and the annual expence of the windmill when erected will be less than that of the other machine"⁷⁶.

Given, then, that the pumping windmill in Fife was fairly cheap, powerful and not so unreliable as we might at first expect, how do we explain its relative unpopularity? The answer lies in the timing of its innovation. Apart from its use in the 17th century by Wemyss, who thought windmills 'very expensive to set up....and very little to govern'⁷⁷, the windmill was not generally applied to the pumping of colliery water in Fife until well into the 18th century. By this time the technology of the water-gin and the horse-gin was already well established in the county. There was no particular lack of sites suitable for the erection of water-wheels, and the flexibility of the horse-gin was well understood. Furthermore, expertise in windmill construction may have been limited. By the time this expertise had become widespread, the inertia of water and horse-gins had carried the industry into the period of predominantly steam pumping. The windmill innovation was too little, too late.

Water power, however, did not suffer this disadvantage, and proved to be a long-lived source of energy for the raising of colliery water.

WATER POWER

At 11 locations on the Fife coalfield mine drainage was accomplished by water-powered engines (see figure 3.6). Introduced to Fife mining before 1590, this source of power was still in use well into the mid 19th century (see Table 3.4). Our examination of water-gin drainage will consider 4 main aspects of the technique. First, we will undertake a general description of the method's innovation in Fife. Second, the efficacy of water power will be looked at, including the depths attained and the significance of the actual mechanism used for raising water. Third, we must consider the reliability of water engines, including systems of ensuring an adequate supply of water, and fourth, the costs of water-gin drainage must be assessed.

The earliest colliery drainage engine in Fife appears to have been a water wheel. It was set up by George Bruce sometime prior to 1590 to drain shallow workings in his Culross colliery and probably worked a chain of buckets⁷⁸. This innovation has been overshadowed by the better documented horse-driven 'Egyptian Wheel' which he later set up on the shore, but it seems that the two engines were working together for some years, so it is likely that the widespread fame which the colliery enjoyed would have helped the spread of water-powered drainage. However, it was more than 40 years before Bruce's innovation was taken up in the Wemyss colliery expansion of the mid 17th century. Cunningham implies that the Kirkland dam was built as early as 1635 to divert water from the River Leven so that it could be used for working the drainage engine of the Kirkland pits⁷⁹. Also, in 1657, Earl David informs us that a 'water work' was to be set up beside the Leven to work a seam 17 fathoms (31.1 metres) deep⁸⁰. Horse-gins working chain and buckets were already in use in the area,

however, and we cannot be certain that the 'water work' was for drainage. It seems likely, though. On the other hand, we can be certain that Methil-hill saw a water-driven chain and buckets in 1662. Powered by water from a cistern, the wheel was supposed to drain the pit and refill the cistern at the same time⁸¹. In the words of Clerk of Penicuik:

"Some schemes of this kind I have known, but found them every bit as visionary as all the attempts have as yet been to create a perpetual motion"⁸².

Of course, Wemyss found the arrangement unworkable and replaced it in 1664 with a system where water was raised to the cistern by horses, thence to work a water wheel and thus drive the chain and buckets. Clearly, this would not have been an efficient arrangement, and only one year later, David had conceived a scheme to bring a lead from the River Ore near Thornton and thus provide a substantial head of water. Gemmell implies that this scheme was carried out but no firm evidence is available in confirmation⁸³.

The next major development of water-powered drainage came in the Leven valley during the second quarter of the 18th century, when new wheels were installed at Kirkland (1730), Balgonie (1731) and Cluny (1740). At Kirkland in 1723 two engines with 40-foot diameter wheels were already working on the chain and bucket system, but one of these was replaced in 1730 by an engine working wooden pumps from a wheel 28 feet in diameter⁸⁴. This was the first major drainage engine in Fife to work on columns of pumps, these having been introduced into Scotland at Alloa less than 20 years previously. They proved so successful that the second Kirkland engine was also replaced and this arrangement continued until 1785, when a wheel support snapped and the machinery was dismantled⁸⁵.

At Balgonie a water wheel was set up in 1731 to drain the coalworks to a depth of 30 fathoms (54.9 metres). However, this engine was overpowered by an increased accumulation of water and was succeeded by a windmill which operated only until 1743⁸⁶. Since the Balgonie case was only the second installation of a 'bob gin' at a Fife colliery, it may be that its early failure was partly brought about by a lack of expertise in its installation and operation in a heavily watered pit. However, the contemporary Kirkland gins did not have this problem, and the later Cluny bob-gin was constructed and for a time run by the experienced Stephen Row, engineer. Thomson describes his presence at Cluny as indicating for the Rothes pits 'an influx of new technology at a professional level which stands out against the rest of the period'.⁸⁷ Despite this, the engine's life was a short one. Water from the Ore powered a wheel of 6.4 metres in diameter which operated two levers, each about 8 metres long, going 9 strokes a minute. The twin pumps were supposed to raise over 44,000 litres in an hour⁸⁸. This seems pessimistic compared with some 91,000 litres per hour pumped by a later Balgonie engine in 1787⁸⁹. Although the Cluny engine was designed for a depth of 24 fathoms (43.9 metres), the coal was found only 16½ fathoms (30.2 metres) below the surface, so the task should have been well within its capability. Despite this, the engine was stopped in 1752 on the advice of Wemyss and Dundas and was dismantled the following year⁹⁰. This suggests that the water engine shown on this spot in a map of 1775 is a different machine, and it is shown as such in Table 3.4⁹¹.

Later 18th century developments are dominated by the pumping engines of Balgonie and Balbirnie erected in the 1780s. At Balgonie,

1786 saw the erection of a 26-foot diameter (7.9 metres) wheel working two sets of pumps of barrels just over 12 inches (30 cm) diameter. This was designed by Green, a Leeds engineer, but constructed with modifications by Henry Renwick⁹². Although the depth of the engine pit was almost 30 fathoms (54.9 metres), the water was delivered at 3 fathoms (5.5 metres) from the surface into a mine or delivery drift⁹³. According to Duckham, this engine was raising nearly 30,000 litres a day in 1787⁹⁴. This seems odd, since it was designed to draw up to three times this amount. In fact, it drew the smaller amount from the 'windmill waste' only, and must have been pumping a total vastly greater. In January 1817, Bald found the beams very much decayed and recommended a temporary repair until better profits could justify a more substantial job. He also found the engine going only $7\frac{1}{2}$ strokes a minute instead of 10 or 12, a speed which allowed water to accumulate in the workings. He found this was due to a clogged tail race and advised that it be cleared out⁹⁵. This was done, and $2\frac{1}{2}$ years later he found the engine in a much better state⁹⁶. This emphasises the importance of maintaining drainage machinery in good condition. A water wheel was most efficient when running at the speed for which it was designed, and the Balgonie wheel appears to have been somewhat neglected during the period prior to Bald's inspection. However, the fact that the suggestions were speedily implemented implies an optimistic attitude on the part of the colliery management which employed him. Although this engine still appears on a map of 1830, and was probably still working then⁹⁷, it is referred to in a Balgonie lease of 1849 in terms which imply that it was now inoperative⁹⁸.

At Balbirnie, the story of the water-gins is more complex and Thomson, for example, seems to confuse a Balbirnie with a Balgonie

engine⁹⁹. As far as can be ascertained, the picture is as follows. It appears that an engine with a 26-foot (7.9 metres) diameter wheel was erected in the 1770s South of the Leven. Sometime between 1780 and 1794, two additional engines were erected, having wheels of 30 feet (9.1 metres) diameter and located just East of Balbirnie Bridge¹⁰⁰. The first engine seems to have been stopped by April 1814, when Bald made an inspection of the colliery but the two larger engines, turning 7 revolutions per minute, were each working a pair of 15-inch (38 cm) diameter pumps and successfully raising water from over 24 fathoms (43.9 metres) to a mine about 4 fathoms (7.3 metres) from the surface. Bald found both machines 'excellently constructed, well kept, and in good order'¹⁰¹, but recommended some repairs to the East wheel which, despite his previous comment, he found 'a little decayed'¹⁰². A steam engine at Coul, North-West of Balbirnie, will have been assisting drainage by 1828. Nevertheless, the NSA for Markinch, dated 1840, implies that Balbirnie drainage was mainly by water power at that time, though possibly by only one engine¹⁰³. The Ordnance Survey map of 1854 shows two pumping engines on the site, and it may be that one was disused but not dismantled¹⁰⁴. Workings continued up until 1890, so it appears that water power continued to function here until the later part of the 19th century.

Despite this longevity, the setting up of these engines in the late 18th century was the last major development for Fife's water-powered drainage. We cannot date the other wheels precisely, but they are unlikely to have been later than 1800, except for the engine at Kiersbeath and the proposal for Outh. The former was set up sometime before 1820 and worked underground to raise water from a dip winning in the Splint coal. The water which powered the wheel was returned to the engine pit bottom, along with the water which had been

raised, presumably so that the main pumps could lift it to the surface¹⁰⁵. It may well have been the Kiersbeath example which prompted a reference to this kind of arrangement in the 'Edinburgh Encyclopaedia' of 1830¹⁰⁶. The Outh proposal came from Bald in 1811, but its viability depended on a considerably increased demand for the coal and it appears never to have been built¹⁰⁷. Nevertheless, water gins were fairly efficient drainage machines, especially where only moderate amounts of water were to be raised, although at both Durie and Balgonie there were engines which were 'overpowered by the increased accumulation of water' and the Wemyss 'perpetual motion' machine simply didn't work¹⁰⁸. At Balbirnie, care had to be taken to minimise the load on the water engines. Bald warned that if the day-level water were to find its way to the engines it would most likely overpower them, and he recommended the propriety of draining surface water, in case it found its way down to the workings¹⁰⁹.

Contemporary writers recognised the effectiveness of water power, especially where it was available without undue expense. For example, Sinclair thought that 'water works' were more powerful than 'horse works'¹¹⁰ but Clerk was more precise:

"(water) power I have seldom found sufficient to draw up any quantity of subterranean water, unless it consisted of a fall or sheet about 2 feet in breadth, and 1 foot or 10 inches in depth. Less water, no doubt, will serve, where the springs and feeders in the coalfield are very moderate....those who can be furnished from a neighbouring river, with any quantity of water they want, may undertake anything....."¹¹¹

Writing nearly 100 years later, Bald felt that the simplicity of the water gin made it very cost-effective but implies that it had by then reached the limits of its potential:

"Many attempts have been made to improve this engine, and to render its powers more efficient, but without success"¹¹²

However, these limits do not appear to have been reached in Fife, except at Kirkland. Here, 2 engines raised the water from 62 fathoms (113.4 metres) to a drift 7 fathoms (12.8 metres) below the surface. Bald implies more than once that about 60 fathoms (109.7 metres) was the limit of water-powered drainage but in Fife, water gins were not generally called upon to drain deeper than about half this amount¹¹³. Duckham puts the point more emphatically:

"But despite the obvious effectiveness of such machines they could not cope with seams lying below 30-40 fathoms (54.9 - 73.2 metres) with any ease - as earlier experience in the great Northern coalfield of England had demonstrated. Before the century had run its course there were many who, with the parish minister of Scoonie in Fife, lamented that coal seams were wrought out as far as water engines could reach"¹¹⁴.

There are two implications here which we might enlarge upon. First, it is implied that water engines found it difficult to cope with seams below 40 fathoms (73.2 metres). While this may have been true for individual engines, particularly if driving a chain and buckets, the method of coping with deeper pits had been well known since the mid 17th century. The technique was to raise the water in a series of steps or 'lifts', commonly employing more than one pit and more than one engine. A sketch by Lord Wemyss dated 1662 shows that he was familiar with the method¹¹⁵, and a description was published by Sinclair only some 20 years later¹¹⁶. Sinclair does indicate, however, that only one sink was employed in Scotland, and it may be that this is simply a reflection of shallower Scottish pits. The method was applied at Kirkland in a modified form. Here, about half the water was raised in 3 stages of pumps operated in one pit by the new engine. The other half of the water was first raised 19 fathoms (34.7 metres) then allowed to flow to the old engine pit, where it was raised to the surface by the old engine¹¹⁷.

Duckham's other implication is that water engines had reached their limit in, among other places, Scoonie parish. What the OSA actually says is:

"....This seam, so far as it could be drained by the present water engine, is now exhausted.....By an additional engine, the proprietor will have the command of a large field of the principal or better seam"¹¹⁸.

There is thus an alternative interpretation. If the envisaged 'additional engine' is a water gin, then the method had not reached its limits in Scoonie parish. Nevertheless, this particular engine had reached its limit and the power output of an engine would impose a limit on its drainage depth. For example, in 1787 the Balgonie engine was unable to command a greater depth than just over 20 fathoms (36.6 metres)¹¹⁹. We must bear in mind, however, that this was due to 'the great quantity of water unexpectedly met with in sinking' and, given certain modifications in the underground workings, it was within the power of this engine to go to 40 fathoms (73.2 metres)¹²⁰. Earlier, at Culross, the wheel erected by Bruce drained shallow workings successfully but as the workings went deeper, a horse gin had to be set up¹²¹.

It may be that these limitations in pumping power were partly due to the fact that none of the gins had overshot wheels. For example, the wheels at Balgonie and Balbirnie were breastshot¹²², while the well-known Rothes illustration of the Strathore bob gin (see figure 3.7) shows an undershot wheel. The only evidence we have of an overshot wheel in the area is from Carsebridge, Alloa, where a winning was made in 1760 with a 'hydraulic engine of considerable power'¹²³. It may be that the apparent lack of overshot wheels at Fife collieries is due to difficulties in obtaining the required head

of water. For instance, in recommending a windmill for Strathore in 1738, Lord Elphinstone summarises some of the problems of water power:

"The aqueduct would be upward of 2 English milles in length and it would require a great charge to bring it from the dam to the water pit, and we are apprehensive from the smallness of the stream that the greatest part of the water would be losed by the way in dry summers or frosty winters, and as Lord Rothes is situated, the erecting of a sufficient damhead over his own ground, would probably involve him in a lawsuit with a neighbour."¹²⁴

The efficiency of drainage engines depended not only on their power but on how that power was applied and the original chain and buckets system had to be replaced before deeper pits could be adequately drained. The chain and buckets or 'Egyptian Wheel' consisted of an endless chain or chains to which were fixed a series of wood or leather buckets. Driven by the axle of a water wheel, this chain pump continually brought water to the surface where it was tipped into a trough and led away. Two disadvantages were highlighted by Bald, first, where he points out that the only way to regulate this system was to take off buckets when there was a lack of water to power the wheel, and second, when he remarks that water was constantly pouring down the pit 'like a deluge',¹²⁵. Clerk also found the chain and buckets unsatisfactory, since it worked 'with so much friction and so much loss of water that I think the whole apparatus does by no means answer its design',¹²⁶. Nevertheless, in the absence of anything better the chain and buckets served Fife coalmasters well enough after its introduction to Culross by George Bruce, and was still to be found working at Kirkland after 1730.

In some parts of the country, the 'deluge' in the shaft was prevented by attaching circular plates to the chain, which ascended through a column of pipes, like so many pistons. Sometimes, a bunch

of rags was substituted for plates. We have no evidence of this technique in Fife mine drainage, perhaps because it was not all that significant an improvement on the conventional chain and buckets. Clerk dismissed rag and chain pumps as 'of little or no service on a coalfield of any extent and value',¹²⁷.

Despite these problems, Bald points out that in Scotland, water was raised in one lift from 40 fathoms (73.2 metres) by the chain and bucket¹²⁸. Here, Bald seems to be referring to the 18th century. Galloway, on the other hand, may be referring to the late 17th century when he claims that to raise water by chain pumps from 40 fathoms (73.2 metres) was considered a great performance and to accomplish this in one lift was 'quite beyond the power of the appliances in use',¹²⁹.

Clearly, any significant improvement in mine drainage required a new method of lifting the water. This came to England about 1680 and to Scotland about 1712, and consisted of a long column of pumps, the rods being worked by a water wheel through a system of cranks and levers.

In a pit up to about 30 fathoms (54.9 metres) in depth, two piles or sets of pumps reached from top to bottom of the shaft, but in a deeper pit the depth was divided, one set raising the water to a cistern halfway up the pit and the other completing the lift. At Kirkland, for instance, the new engine of 1730 wrought four sets of pumps, consisting of two bottom sets, a middle set and an upper set, but generally, the depth of pits drained by water engines in Fife was shallow enough for one lift to be sufficient.

The initial innovation of pumps to Alloa, Clackmannan, is quite well known. George Sorocold, the engineer, was employed by the Earl of Mar in 1710 to prevent flooding in the Earl's Alloa collieries.

He advised pumps in place of chain and buckets but 'there was no person in Scotland who could construct such pumps as were required'¹³⁰. Consequently the winning was drained by chain and buckets but soon superseded by pumps worked by a bob gin (ie a water wheel with cranks and beams).

In Fife, wooden pumps were introduced to Kirkland in 1730 and Elphinstone's recommendations for Cluny in 1738 envisaged the main alternative to a windmill as a bob gin working pumps by cranks. When the Strathore engine was built, however, its cranks and pump barrels had to be imported from England. The pumps were probably similar to those described in the NSA for Alloa, where the Coalyland winning was achieved by a Newcomen steam engine in 1764:

"All these pumps were of plane-tree, bored out of the solid wood, hooped with iron, having spiget and faucet joints. The only pipes in the two columns made of cast iron were the working barrels"¹³¹

These Alloa pumps were of 25 cm diameter, and the various pumps in Fife for which we have figures suggest that this is about average, the range being from 19 to 38 cm diameter for the working barrels. Clearly, the larger pumps would be more effective but would require a greater power output from the water wheel. Pumps were always installed in pairs, apparently because of the simple fact that a crank could be attached to each end of the wheel axle and thus drive two levers. This raises an interesting problem in figure 3.7. Here, the 'calculation' clearly refers to two 7.5 inch pumps but the picture shows four pump rods, two on each lever. There should have been no need for a two-stage lift in a winning designed to be only 24 fathoms (43.9 metres) deep. It may be, therefore, that the picture is meant to be simply an illustration, an example, and only the figures given alongside are specific to the proposed winning. If so, we must beware

of the assumption that the picture shows the machine as built by Row¹³². This also throws doubt on our own assumption that the Cluny gin was undershot. On the other hand, figure 3.5 shows a two-stage lift in a sinking of only 20 fathoms (36.6 metres). It may be, therefore, that the 'calculation' should refer to two sets of pumps.

In general, the innovation of pumps was very swift in Fife. From nearby Alloa about 1712, the technique appeared in Kirkland, Wemyss, in 1730, Balgonie in 1731 and Cluny in 1740, by which time the chain and buckets system had largely disappeared from the Fife coalfield. More significantly, the innovation was to make possible the application of steam power to large-scale colliery drainage. In the meantime, though, pumps had rendered far more efficient the power of the water wheel. Its reliability is another question, however.

Water power was certainly unreliable for the continuous task of lifting pit water but this was mainly due to the occasional lack of driving water rather than to any fault in the machines. Bald implies that there was very little that could go wrong with a water engine:

"This machine is of very simple construction; the working parts are few, and requires no attendance..."¹³³.

while Thomson has shown that the Strathore machine was rarely out of order despite the fact that sumps had been provided in case the gin broke down and that some early problems had arisen out of the poor quality of leather used in the pumps¹³⁴. Thus although various repairs had to be carried out on a Balbirnie engine in 1814¹³⁵, the only major failure of machinery occurred at Kirkland in 1785 with the collapse of a wheel support¹³⁶. Writing in 1808, Bald refers to the chain and buckets as being very expensive to keep in repair while the bob gin with pumps was so easily maintained that it put the seams nearly on a footing with level-free workings¹³⁷. We have seen that

by about 1740 the more reliable pumps had superseded the chain and buckets system, so we are dealing with a mechanical design which was by mid-century well understood and remarkably reliable.

On the other hand, water supply was a continuing problem. Clerk of Penicuik emphasised the need for a regular supply of water as follows:

"the above quantity of water will be necessary both Summer and Winter and at all times of the day and night, for it seldom happens that ponds or reservoirs collected from rains or small springs can signify any¹³⁸ thing, where a large quantity of water is to be drawn".

About the same time, Lord Elphinstone was clearly aware of this problem when he recommended against a water engine at Strathore¹³⁹. He was apprehensive that the small flow could be unreliable in times of drought or frost, and had his misgivings confirmed in the summer of 1747, when there was a failure of the water supply to the machine. At Kirkland, too, dry summers sometimes resulted in a failure of the power source, and the management had to heighten the damhead by erecting boards. In extreme drought it was known for men to be sent to Loch Leven to dig trenches so that they might produce a greater flow of water from the loch¹⁴⁰. Duckham's opinion, on the other hand, is that water wheels were generally more reliable than windmills, but this reliability had to be promoted by various engineering schemes for the provision of water. The earliest was certainly that at Culross, where Bruce's original water wheel was powered by a diverted Dean Burn¹⁴¹. At Kincardine, the Papermill dam produced a body of water some 66 acres (26.7 hectares) in extent which was enough to drive the 'coal machinery' as well as the mills¹⁴². The Kirkland dam provided Leven water for some 150 years of mine drainage, and at Durie an unusual scheme was adopted whereby a mine was driven to divert water from the Kennoway Burn through the craig of the Maiden Castle and into a lead

some 3.5 Km long. This scheme also drained the lochs of Banbeath and Durie, and the tunnel may still be seen at NO 350015¹⁴³. Unfortunately, we cannot as yet put a precise date on these developments.

After completion, any water-supply scheme would need to be maintained in good order. For example, in November 1747 the 'Instructions anent Cadham and Clunie Coalwork', perhaps prompted by the water problems of that summer, required:

"that the locks and dams be visited regularly to prevent any stop in the work for want of water, and that it may not be wasted by the neglect of the Millers and an annual bounty to be continued to them for their care"¹⁴⁴.

Such maintenance costs must be added to the capital expenditure on water-powered drainage, and although an accurate assessment of the former is not possible, there is at least some evidence on which to base an estimate of the latter.

Duckham's figure of £250, echoed by Stephen and by Thomson, is apparently based on the estimate for the Balgonie engine built around 1786¹⁴⁵. Although this is for a 'water machine - compleat' it does not appear to include the cost of dam, lead or pumps. Confirmation of this figure comes from Cluny, built in 1740. Here, an estimate by Stephen Row gives a cost of just under £230, an amount which Thomson believes to be fairly accurate and which is a good approximation to the Balgonie figure¹⁴⁶.

The expense of sinking would have to be added to this sum, but would also be an element for other types of drainage engine, as would pumps. An additional cost unique to water engines, however, is the charge of obtaining water, and we have seen that considerable pains were taken to ensure an adequate and reliable water supply. These systems varied to such an extent that any generalisation would be meaningless. It is likely, though, that any investment here would in

many cases be considerably more than the cost of the engine itself. For example, it may be that the 1761 estimate for an unspecified engine at Cadham, considered excessive at £751, includes the cost of water supply for a wheel¹⁴⁷. Certainly, Elphinstone's view of the Cluny situation was that a 2-mile aqueduct would have to be built at 'a great charge'. In addition 'the tail lead and the arc for the wheel would take a very considerable charge besides what would be necessary to keep the damhead and aqueduct in constant repair'¹⁴⁸. Despite this, the water-gin must have been cost-effective for the typical Fife depths of about 30 fathoms (9.1 metres), otherwise Bald would scarcely have proposed one for Outh as late as 1811, although he felt a steam engine was out of the question¹⁴⁹.

Generally, we may conclude that in the context of Fife mine drainage, the water-gin was a moderately reliable, easily maintained and cost-effective machine. It was probably more powerful than we might have come to expect and represented a valuable 'transition' technique in the shift from horse to steam power, particularly in its alliance with columns of pumps. The distribution of water-gins was, of course, restricted by the availability of water supply and was thus concentrated in the Leven/Ore valley, but even in favourable locations, the demands of an expanding coal market eventually pushed mining to a depth which water power could not effectively drain, and by the beginning of the 19th century, its period of supremacy had passed.

TABLE 3.1 - DRAINAGE METHODS IN FIFE COLLIERIES c. 1800

Method	No. of collieries
Steam	12
Day-level	30
Wind	1
Water	4
Horse (probable)	21
Total	68

TABLE 3.2 - COLLIERIES PROBABLY HAVING HORSE-GIN DRAINAGE c. 1800

Colliery	approx. 6-fig. ref.	Colliery	approx. 6-fig. ref.
1. Markinch	NO 305015	12. Lundin	NO 390035
2. Buchlive	NT 173886	13. Letham	NO 377043
3. Whinnyhill	Carnock parish	14. Pitlessie	NO 340090
4. Valleyfield	NT 010864	15. Clatto	NO 358072
5. Burnturk Muir	NO 335073	16. Drumcarro	NO 455129
6. Preston Island	NT 007852	17. Ladedda	NO 44 5132
7. Blairhall	NT 005895	18. Cults Hills	NO 345082
8. Doan	NO 340058	19. Lassodie	NT 125928
9. Clothie	Kettle parish	20. Prathouse	NT 136884
10. Lochore	NT 172970	21. Pilmour	NO 395038
11. Star	NO 322035		

TABLE 3.3 - WINDMILLS IN FIFE

Name	Probable date	Function	Approx. 6-fig. ref.
1. Chapel	before 1837	limestone drainage	NT 253939
2. Leven	before 1719	saltpans	NO 384006
3. St Monance	about 1780	saltpans	NO 533019
4. Inverkeithing	about 1750	agriculture	not known
5. Prathouse	before 1819	agriculture	NT 144882
6. Torryburn	not known	agriculture	NT 028856
7. Hillhouse	17th century	agriculture	NT 091859
8. Collessie	not known	agriculture	NO 298142
9. Rameldry	before 1818	coal ?	NO 335062
10. Largoward	before 1775	coal ?	NO 474088
11. Callange	not known	coal ?	NO 420122
12. Crossford	before 1775	coal ?	NT 066874
13. Kingsmuir	before 1794	coal	NO 550090
14. Wemyss	1676	coal	NT 328951
15. Kinninmonth	18th century	coal	NT 213994
16. Balgonie	early 1730's	coal	NO 311007
17. Powguild	18th century	coal	NT 209927
18. Kellie	1746	coal	NO 521048
19. Dysart	about 1800	coal	NT 299935
20. Strathore	planned 1738	coal	not built

TABLE 3.4 - WATER-GINS IN FIFE COLLIERY DRAINAGE

Name	Date(s) of operation	Pit depth fathoms (m)	Wheel diam. feet (m)	Approx. 6-fig. ref.
1. Kiersbeath	? - 1820	not applicable		NT 132898
2. Cluny (a)	1740 - 1753	16½ (30.2)	21 (6.4)	NT 244963
3. Cluny (b)	c. 1775			NT 244963
4. Inzievar	before 1835			NT 010890 - 020890
5. Kincardine	before 1794			NT 942873
6. Dundonald	before 1825			
7. Durie	before 1791			NO 377015
8. Kirkland	1635 - 1785 *	62 (113.4)	40 (12.2) 28 (8.5)	NO 367005
9. Culross	before 1590	5 (9.1)		
10. Methil-hill	after 1662		18 (5.5)	
11. Balgonie (a)	1731 - c. 1740	30 (54.9)	under 26 (7.9)	
12. Balgonie (b)	1786 - 1830/49	30 (54.9)	26 (7.9)	NO 307005
13. Balbirnie (a)	1770's - before 1814	24 (43.9)		
14. Balbirnie (b)	1780's - after 1854	24 (43.9)	30 (9.1)	NO 288016
15. Balbirnie (c)	1780's - after 1854	24 (43.9)	30 (9.1)	NO 288016

* - There were various wheels at Kirkland during this period. The depth given refers to an engine pit of about 1730. The two sizes refer to the change in that year from a chain pump to a bob gin with a smaller wheel.

Note - A wheel was proposed for Outh in 1811. It seems not to have been built.

Figure 3.1 COG AND RUNG GIN WORKING A CHAIN AND BUCKETS

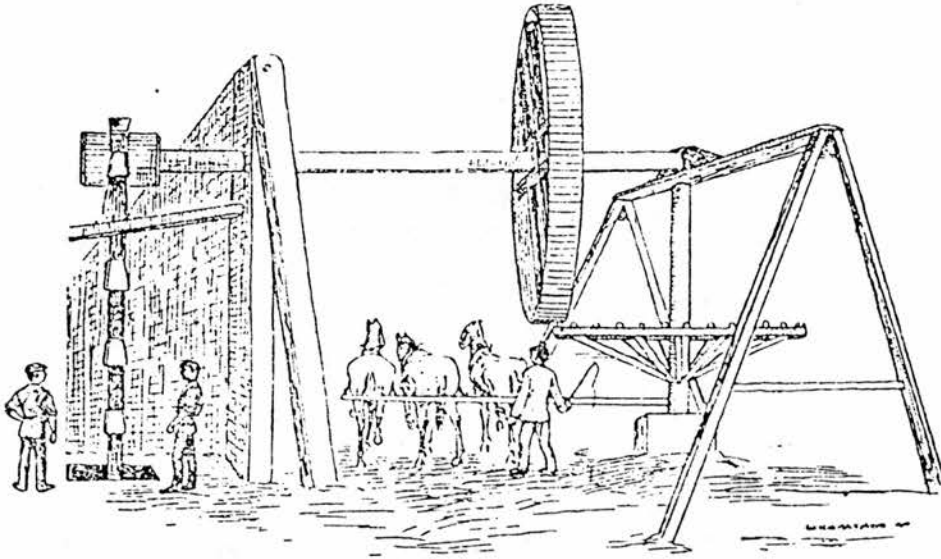
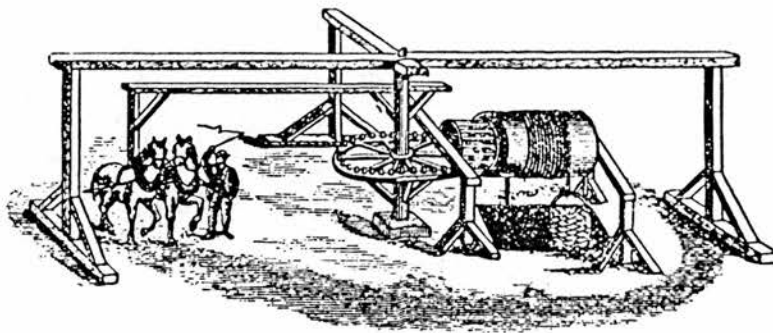


Figure 3.2 COG AND RUNG GIN SET UP FOR WINDING ON A DRUM



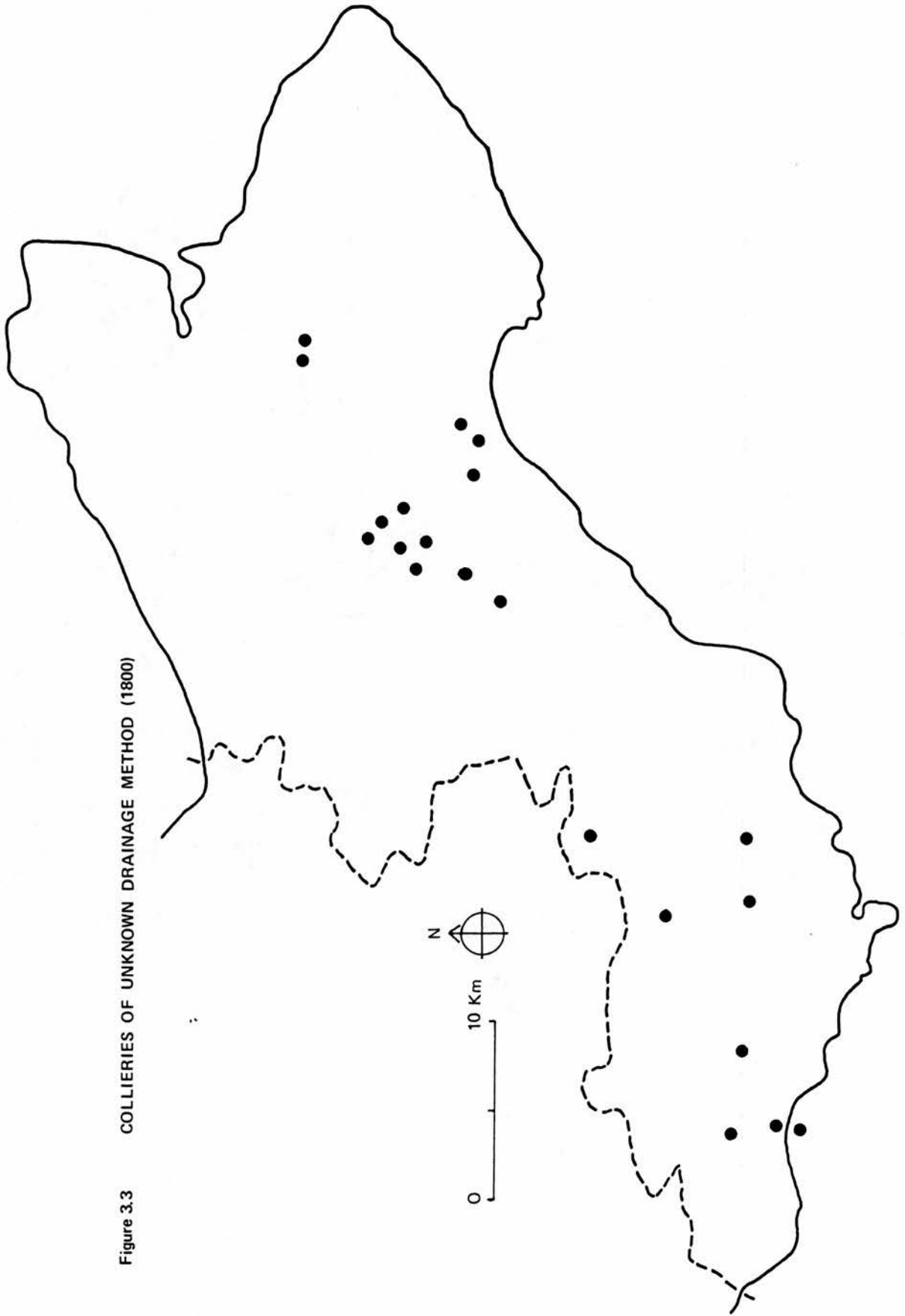


Figure 3.3 COLLIERIES OF UNKNOWN DRAINAGE METHOD (1800)

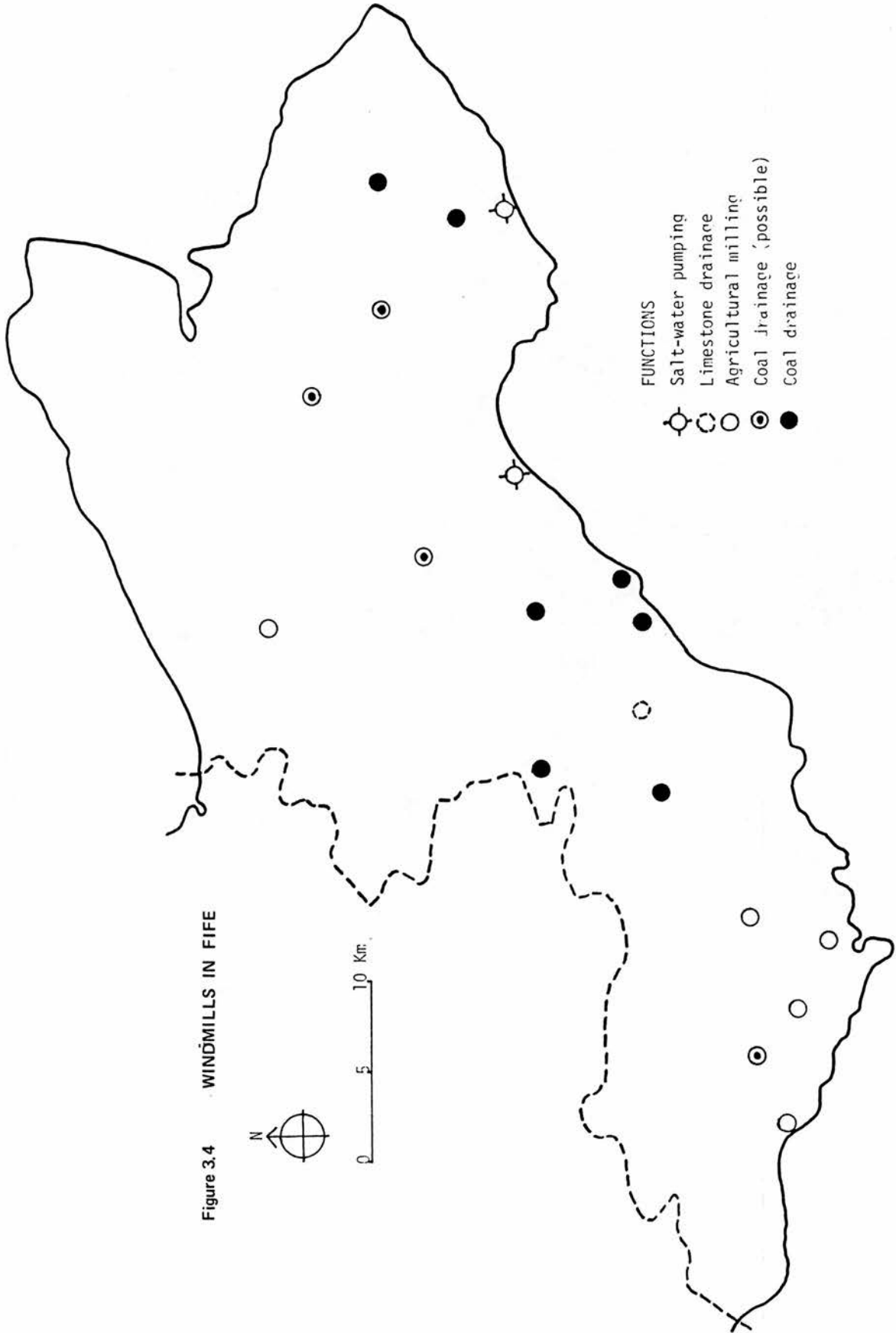


Figure 3.5

PLAN FOR WINDMILL AT STRATHORE (1738)

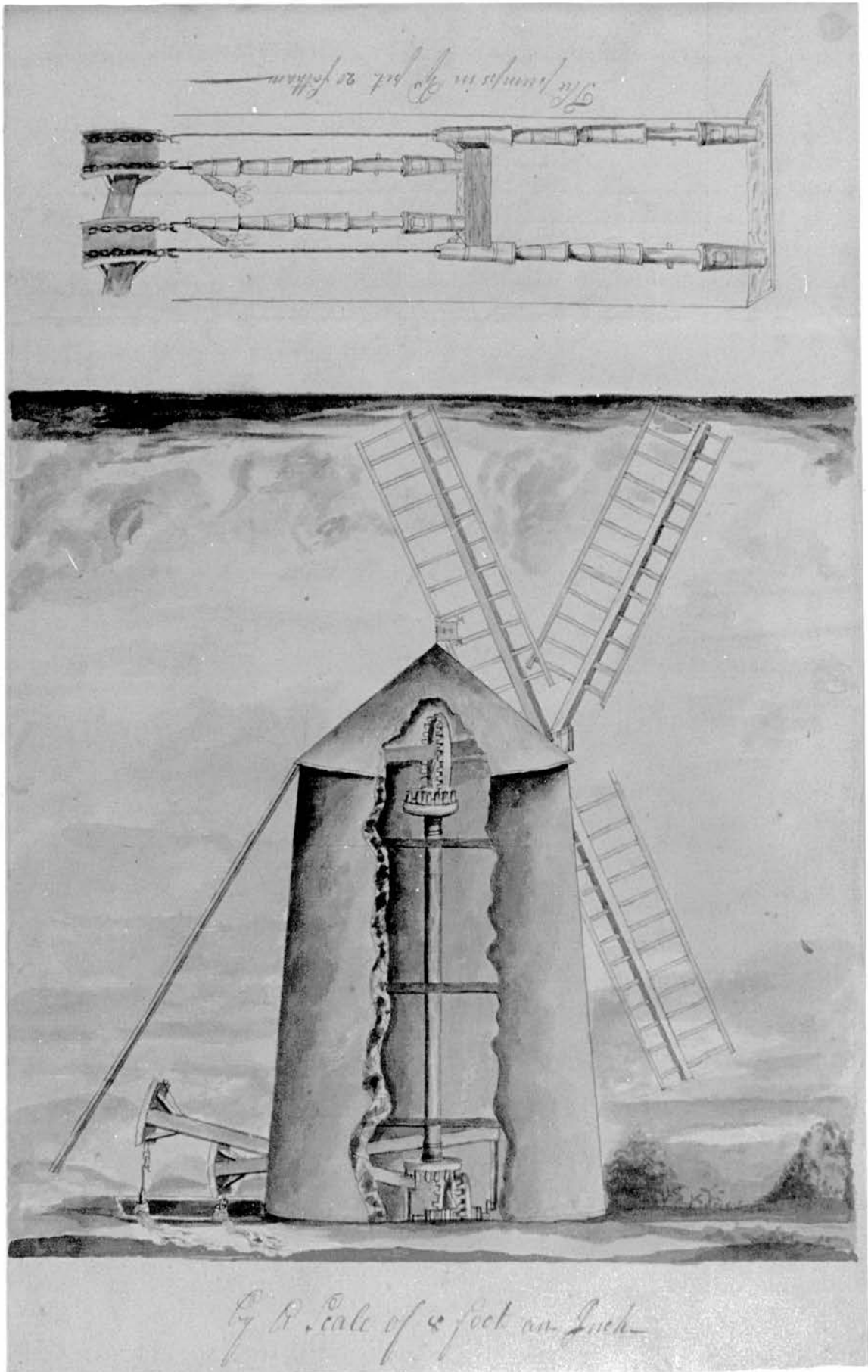


Figure 3.6 WATER-GIN DRAINAGE ENGINES IN FIFE

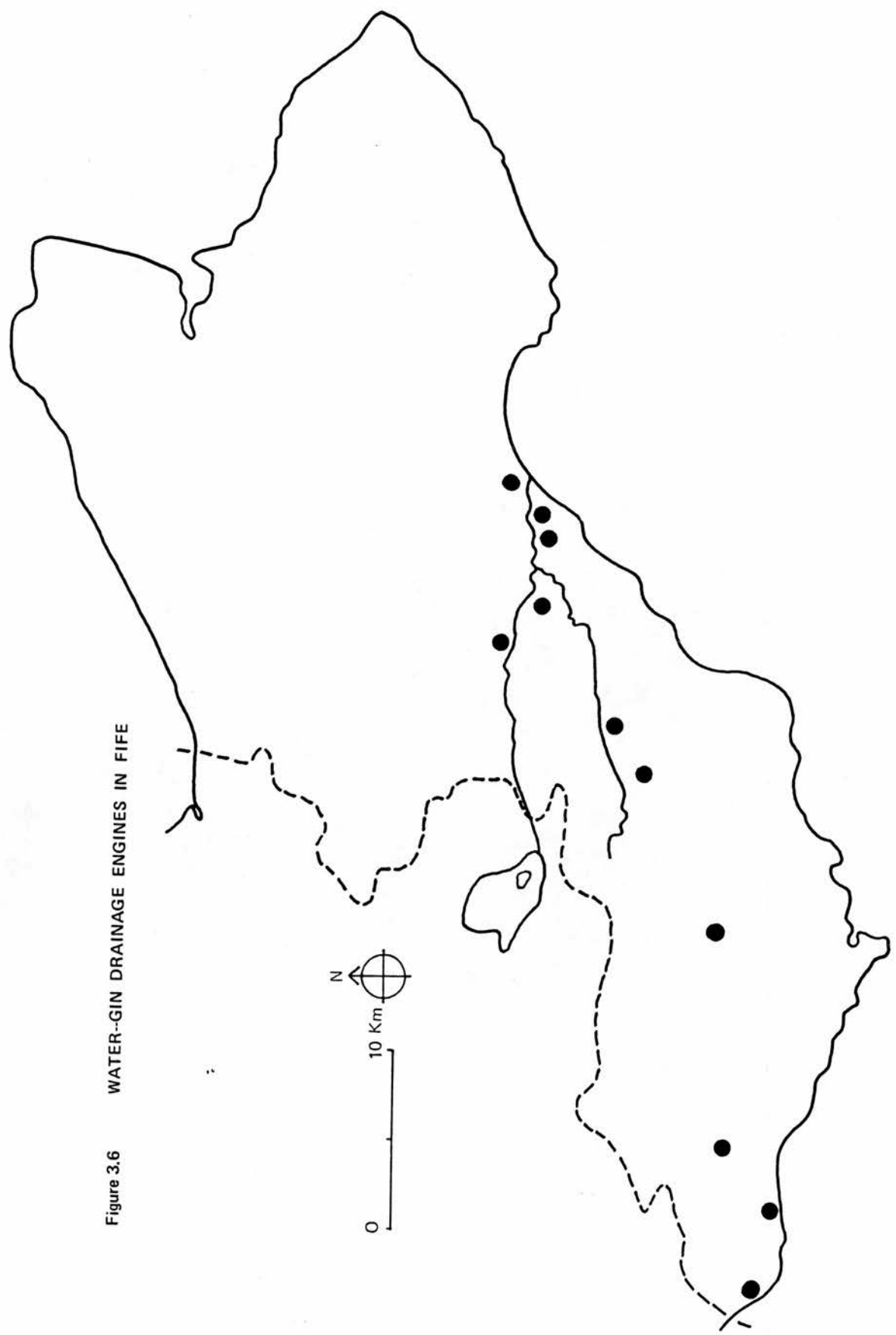


Figure 3.7 PROPOSED WATER-GIN AT CLUNY (1736)



CHAPTER 4 - STEAM-POWERED DRAINAGE

The drainage of collieries by steam engines has been described by Smout as "the only important innovation underground" throughout the whole of the Industrial Revolution period¹. Although this is an exaggeration, we must accept that steam pumping was indeed very important - probably the most important single innovation in the technological history of coal mining. However, we must beware of oversimplification, since steam pumping is not one innovation but several, with its roots going back at least as far as the Seventeenth Century, and still developing alongside the electric pumps of the very late Nineteenth Century.

We will begin with a detailed look at the innovation process in Fife, from the first installation at Dysart in 1754 to the building of the massive machines of the early Twentieth Century. We will then examine the effectiveness of steam pumping through eight different characteristics of the machines and their task. This will be followed by a look at the reliability of steam pumping technology and finally, by an examination of costs, including both capital investment and the question of fuel consumption.

Of the scientific developments of the Seventeenth Century, perhaps two are of particular significance for the innovation of steam pumping. The first was the identification of atmospheric pressure by Torricelli in 1644 and the second was Papin's use of condensed steam to create a vacuum in 1690. The early working steam engines made use of these discoveries, but the engine patented in 1698 by Thomas Savery failed to make any impact on coal winning. In Savery's engine, steam was condensed to form a vacuum which drew water from below, the next injection of steam forcing this water upwards. Deeper mines could

only be drained by using more than one engine to lift the water in stages, and although the Savery engine was successful in some situations, its main significance for the coal industry was the fact that the Savery patent ran until 1733, and provided the umbrella under which the much more effective Newcomen engines were to be built and sold.

Thomas Newcomen's invention of 1705 was a much more practical proposition for the mining engineer. A long beam was pivoted see-saw fashion, having one end attached to the pump-rods in the pit and the other to a piston which was free to move in a long cylinder (see figures 4.1 and 4.2). The weight of the pump-rods pulled down on the beam and thus raised the piston. Steam was passed from a boiler into the cylinder and then condensed by a jet of water, so producing a partial vacuum under the piston. Atmospheric pressure then forced the piston down, thus raising the pump-rods by the see-saw beam. A further injection of steam allowed the piston to rise, pulled up by the weight of the pump-rods acting on the beam.

The Newcomen engine was not properly a 'steam engine' at all, using steam only as an agent for the creation of a vacuum. The motive force was applied by atmospheric pressure, thus giving the contrivance its proper title - 'Atmospheric Engine'. This meant that steam at roughly atmospheric pressure could be employed, so eliminating the problem of weak boilers which had been a major limitation of the Savery design. Also, the power could be increased simply by enlarging the diameter of the piston and cylinder. A third advantage over the Savery engine was that the Newcomen plan eliminated the loss of heat due to contact with the water being pumped. However, the pumps themselves were an essential part of the machine's working since the weight of the pump-rods was necessary to raise the piston during each

upstroke. In summary, the Newcomen engine was more reliable, safer and altogether more powerful than that invented by Savery. Given this, it is little wonder that it made rapid progress as an innovation in coal mining technology.

Although taken up with enthusiasm in England, the Newcomen engine had a slightly slower start in Scotland, probably due to the fact that many Scottish colliery operations were comparatively small scale until the expansion of demand in the mid Eighteenth Century, and so could not justify the capital investment. It seems that Tranent, East Lothian, saw the first steam pumping in Scotland in 1719, followed in 1720 by an engine at Elphinstone, Stirlingshire and in 1725-6 by one at Edmonstone, Midlothian². Despite Cunningham's claim that "this example was soon followed in Fife"³, it was not until 1754 that a steam engine was erected at Dysart⁴. A second was added to this colliery before 1783⁵ and henceforth the pace of innovation increased so that by 1800, there were certainly no fewer than 15 steam pumping engines on the Fife coalfield, including 3 which were in parishes at that time part of Perthshire. Their locations are shown in figure 4.3. Duckham's map confirms this total, showing 15 engines in all, but in his list he gives a minimum total of 17-18⁶. A double counting of the 3 Perthshire engines would account for this discrepancy. Although it is of course possible, it is thought unlikely that there are any steam pumping engines in Eighteenth-century Fife which remain unaccounted for. As for the geographic pattern of the succeeding spread of steam drainage, this is shown in figure 4.4.

Three features seem to dominate the pattern of innovation sites. First, in the Eastern part of the County there is a scattering of 8 sites, 6 of which are pre-1800 and 2 from the first half of the Nineteenth Century. This suggests that the main development of steam

power in this part of Fife took place early but failed to maintain a significant impetus. Second, there is a pronounced concentration of sites in the Wemyss area, with examples from all three periods, which implies a long phase of consistent development throughout that parish. Third, a long "belt" of sites runs from the Lochgelly area in West-central Fife through Dunfermline to Kincardine in the far West, again showing evidence of steam innovation during all three periods, although there is a slight tendency for the more recent sites to be found East of Dunfermline.

The distribution may also be examined by taking each period individually. The 12 sites in the pre-1800 group are widely scattered through Fife. Goodwin's view is that Dysart may have been among the first of the local pits to employ steam pumps because the absence of suitable surface streams in that area would have made it impossible to use a water engine⁷. While this may be true of Dysart, it seems reasonable from a comparison of the map data to regard this "lack of alternatives" idea as only one in a complex of factors which led to the spread of this drainage technique. Nevertheless, in comparing the distribution in figure 4.4 with the location of other drainage engines, one group of pre-1800 steam sites does rather stand out on its own, which is the four engines installed on the high land in the centre of the Eastern peninsula. Unfortunately, we know little about these sites and cannot even pinpoint exact locations. The four engines concerned are all mentioned in the OSA and are: One at North Falfield; one in Ceres parish; two in Cameron parish. Only in the case of the first is a firm erection date given - 1784 - and is the location reasonably precise⁸, although one fact which may be of some significance in the innovation process is that the Falfield engine, like those in Cameron parish, was erected by Mr J C Durham of Largo⁹. Clearly, a

coalowner who had successfully erected one engine would be quick to erect another in appropriate circumstances. These could not have been appropriate at nearby Largoward, also owned by Mr Durham, for drainage here was by day-level.¹⁰

The period 1800-1850 saw the appearance of 23 new sites, and only 2 of these were East of Leven. There is a definite concentration around Wemyss and the emergence of a "belt" North and North-East of Dunfermline. The 7 sites dating from after 1850 serve to intensify the two clusters already set up. The Nineteenth-century concentration and Westward shift of the Fife mining industry is thus well illustrated in the distribution of the sites of steam pumping innovation, and it is no coincidence that this process is mirrored in the concentrations of population evident in later Nineteenth-century Fife.

A complementary view of the innovation process over time is gained from figure 4.5, which gives the earliest dates by which steam pumping is known to have been in operation at 42 different locations in Fife. In several cases the actual date of engine erection is not known and in this event the earliest confirmed date has been plotted. Despite this limitation of the data, the general trend of the graph follows a typical s-shaped innovation pattern. A slow 'take-off' from 1754 to about 1780 is followed by a period of 70 years where there is a fairly steady rise, levelling off again after about 1850, by which time the innovation of steam pumping had only a few more locations at which it could appear. Of the 42 innovation dates recorded, only 2 came before 1780 and only 7 after 1850, which accords well with Duckham's view for the Scottish coal industry as a whole that most investment in steam engines had come after 1770 and probably after 1780.¹¹ Smout, too, puts the date at 'after about 1780 in most places'.¹²

A more detailed examination of figure 4.5 shows three minor features, but these appear to be quirks of the sources of data rather than real changes in the rate of steam innovation. First, there is a sharp rise in the graph during the mid 1790s. While this may be taken as confirmation of Duckham's opinion that "By the 1790s colliery investment in steam power was clearly advancing at a more rapid pace."¹³, it is more probably due to the fact that the OSA is a major source of information for the late Eighteenth Century. The erection dates of engines are often omitted from these accounts, so the earliest hard evidence of their existence is the date of the relevant OSA volume.

Second, there is a period of some 15 years after 1795 when only one new location is identified, suggesting a lull in the innovation process. A lull seems unlikely during what was actually a 'boom' in the demand for coal. Prices climbed rapidly and collieries were hard pressed to meet the demand. The fact that our data fails to reflect what we might expect to be an incentive to innovation may be put down to a gap in the documentary record. The immensely useful series of reports by Robert Bald does not begin until 1808 and, as with the OSA, a report often fails to give the actual date of erection of a steam engine.

Third, there is a short but steep increase in the graph during the mid 1840s. In this case 3 out of the 6 engines concerned in the rise are 'dates of first evidence', and may well have been erected some years previously. Consequently, we cannot claim that any of the minor features of the graph represent real changes in the rate of innovation. In any case they do not alter the long term picture in which the main innovation period is shown to have been between about 1780 and 1850. How many of these engines were of the Newcomen design is a more complex matter.

In general, we may agree with Stephen when he thinks it probable that all the Fife engines erected before 1800 were the Newcomen type¹⁴. One Boulton and Watt engine was sent to Kinghorn, but there is no evidence that it was to be erected at a colliery¹⁵. Since Kinghorn parish contained no coal mining of any significance, a colliery location seems unlikely. After 1800 the Newcomen engine still features in the innovation record, but had increasingly to compete with other types.

For example, at Townhill in 1810 the colliery was drained by a steam engine "of the common construction" - probably an atmospheric engine¹⁶, but only two years later at Dysart a new engine was erected "upon Mr Symington's plan, without a beam" in place of the second Newcomen engine which had been put up some years after 1754¹⁷. This is presumably a reference to William Symington, the pioneer of direct-acting steam engines. This process of change had obviously gone some way in Dunfermline parish by 1842, when the 17 colliery steam engines were:

- 13 high pressure engines (mainly for winding)
- 1 condensing engine
- 2 atmospheric engines
- 1 bellcrank¹⁸

Unfortunately, we do not have a similar breakdown for the 17 Dunfermline engines of 1857, so we cannot be sure which had been superseded in the intervening 15 years¹⁹.

As late as 1844, however, one of the three pumping engines at Halbeath was still an atmospheric engine of 30 horse-power, the others being of the high pressure type and used for both pumping and winding²⁰. Even in 1869 an inventory of Cowdenbeath colliery includes at No 1 Pit "one atmospheric pumping engine"²¹. This engine may have

ceased operating soon after this date since in 1871 steps were being taken to centralise the pumping at Cowdenbeath colliery in No 7 Pit²².

Clearly, the inertial use of the atmospheric engine carried on beyond the mid Nineteenth Century and corresponds with Boyd's opinion of 1895 that the replacement of the Newcomen engine took place only by degrees and "even in recent years a few of them were still at work"²³. It is worth noting in this respect that not only did Eighteenth-century machines continue to operate well into the Nineteenth, but new installations carried the Newcomen engine well beyond 1800. For example, in 1820 Bald proposed for Fordell a steam engine "of the common atmospheric construction, with beam and framing of iron similar to the one lately erected upon the Fordell Colliery"²⁴, and in 1835 the coalwork at Kellie was successfully fitted with a "rude old atmospheric engine"²⁵. In 1830, Bald summarised the position as follows:

"Newcomen's atmospheric steam-engine being of very simple construction, is still generally used as a pumping engine in collieries, when the kind of coal used in working them is of little or no value, and when the depth does not exceed 120 yards; for a greater depth, and where pumps are used above ten inches diameter, the improved engine of Watt is preferred."²⁶.

Although Smeaton's improvements in the 1770s had virtually doubled the efficiency of the atmospheric engine, we do not know whether they were incorporated in any of the later Fife engines of this type. Certainly, the reference at Kellie in 1835 to a "rude old atmospheric engine" seems to imply a basic Newcomen design. However, the terms "rude" and "old" may simply be in comparison with the engines of Watt, Symington and others, for even with a variety of later improvements the atmospheric engine remained a machine of comparatively poor performance.

Following Newcomen, the next major development in steam pumping was the introduction of James Watt's separate condenser. Invented in 1765, the separate condenser was patented in 1769 and became a commercial proposition about 1775 after Watt had gone into his famous partnership with Matthew Boulton. Despite this, there seems to have been no Watt engine erected at a Fife pit before the early Nineteenth Century.

Watt's invention stemmed from the fact that the alternate heating and cooling of the Newcomen cylinder led to a great waste of steam. Watt proposed using two connected cylinders, one kept hot, the other cold (the condenser). Steam would fill one then expand into the other where it would condense. Watt also enclosed the hot cylinder in a steam jacket and pushed the piston down with steam instead of air, so keeping up the temperature (see figure 4.6). As a result of these changes there was a very great saving of fuel, but this was of small account at collieries so the simpler and cheaper atmospheric engine continued to be built, even after the expiry of Watt's patent in 1800. This goes some way to explaining the fact that most references to "condensing" engines in Fife come in the mid Nineteenth Century.

For example, a Watt engine "of small power" was barely adequate for draining Baldrige in 1818²⁷, probably due in part to its cylinder being only 16 inches (40 cm) in diameter. However, by 1844 a Watt pumping engine of 70 horse-power had been installed at nearby Wellwood²⁸ and a year later a 200 horse-power engine "on the Cornwall principle" was fitted up at the Queen pit, Halbeath²⁹. Goodwin implies that those erected near Thornton in 1830 and 1846 were this type³⁰ and in Townhill by 1859 a Watt engine was to be found pumping alongside a high-pressure model³¹.

It is not always clear whether these engines were single-acting like the Newcomen design or double-acting, a Watt patent of 1782 by which he powered both up and downstrokes of the piston and which required the application of his famous "parallel motion" device for transmitting upstroke power to the beam. In the same year he also patented a technique for using the steam expansively, it being admitted to the cylinder only during the early part of each stroke, after which its expansive force would drive the piston. The engine at the Queen pit, Halbeath, was this expansive type and in 1849 Henry Cadell recommended one for Wemyss colliery. It was, however, to be single-acting, which seems to be fairly typical of Fife engines at that time. Despite the Wemyss recommendation, an undated document of about the same time favours double-acting engines:

"I think also that pumping engines instead of as is usual being made to lift only one way should be made double powered especially where there are two lifts of pumps in a pit on the outgoing stroke working a forcing lift and on the incoming one a lifting set. By this means the tear and wear as well as the original cost of an engine is greatly reduced."³²

Although Nineteenth-century Fife saw a considerable take-up of the Watt engine, two further innovations complicated the developments of steam pumping at this time. First, there was the introduction of direct acting engines, ie, without a large rocking beam. Secondly, there was the use of high pressure steam. Both these developments were necessary before it was possible to erect powerful pumping engines underground.

In 1812, the Symington engine erected at Dysart appears to have been the first direct-acting pumping engine in Fife, and may well have been one of the earliest in Britain in view of Forster Brown's claim that the first such engine was introduced at Eccleston, St Helens, in 1829³³. However, in 1817 Bald implies that there may have been a

suggestion for converting the Dysart machine into a beam engine:

"...the Great Engine must remain as it is as the altering it into a Beam engine would be attended with much expence, and as the water is kept under that alteration is not absolutely necessary."³⁴

In mid-century there are several references to "horizontal" (direct-acting) engines. In 1840, for instance, Cadell recommended a horizontal engine for underground dip workings at Barncraig, Wemyss³⁵. We know his suggestion was acted upon, for in 1845 he found the engine which had been put up "agreeable to my recommendation of 3rd Nov 1840, is a very good engine for the purpose, and works well."³⁶

Only 4 years later another horizontal engine was recommended for installation in the same area³⁷, and in 1859 the Cuttlehill coal was drained by means of a horizontal, high-pressure engine of about 80 horse-power. 1873 saw the Milton Gas Coal near Lochore worked by a direct-acting engine of 16-inch (40 cm) cylinder, used for both pumping and winding.

Because of the apparent danger, Watt had been opposed to steam pressures of more than a few pounds above atmospheric, but in 1802 Trevithick took out a patent for "Improvements in the Construction and Application of Steam Engines" which involved the use of high-pressure steam. This made possible Woolf's development of compounding, which used the energy remaining in the steam after it had driven the piston, by leading it into a second cylinder of larger dimensions. Woolf produced the first commercially successful compound beam engine in 1804, but its cost and complexity made it uncompetitive and none were installed in Fife. The compound engine had to wait for almost a century before it was taken up with any enthusiasm in the County (see figure 4.7).

Bald was particularly aware of the value of high-pressure engines when located underground to drain dip workings³⁸, and it is in one of his reports that we find our first evidence of a high-pressure engine so employed in Fife. Writing in 1821 of Newton pit, Wemyss, he says that an under-dip breast of coal had been gained by placing a high-pressure engine near the bottom of the pit:

"The growth of water was at first very moderate; and it was drawn up the Inclined Plane by the underground engine every day by means of barrels placed on carriages, and the water poured into the engine level."³⁹

The method of raising water may not have been typical, but the use of a high-pressure engine was soon to become so. By mid-century, at least a further nine high-pressure pumping engines had been installed at Fife pits, some at comparatively small fittings. For example, at Kellie about 1847 a winning was made with a pit only 28 fathoms (51.2 m) deep, fitted with a high-pressure engine for both winding and pumping⁴⁰. Similarly, winding and pumping were both carried out by a small high-pressure engine at Blair, operating by 1843. Originally set up only for pumping, this engine quickly superseded a horse gin by being adapted to draw coals as well as raise water⁴¹. These cases seem fairly typical, for of the 10 high-pressure pumping engines erected by mid-century, 7 performed both pumping and winding and 3 were for pumping only. Surprisingly, some of the dual-purpose engines seem to have been less powerful than the others. The 3 engines used solely for pumping were of 80, 100 and 120 horse-power, while the 3 dual-purpose engines of which the horse-power is known were 10, 20 and 25, with a fourth described as 'small'. It may be that where water was heavy and needed a powerful engine, that same heavy water required that the engine's work output be undivided.

Thus the innovation of direct-acting, high-pressure pumping

engines meant that steam pumping in Fife could follow the general pattern identified by Buxton:

"The entire history of pumping reveals that the pumping engine has gradually moved from the top of the pit to the bottom"⁴²

However, the Fife case suggests that this process was well under way by about 1850, and not as proposed by Buxton, only beginning about that time. Some of the difficulties of underground installation are illustrated in a series of reports on Wemyss Barncraig workings in the 1840s. In 1840, Cadell recommended an underground engine both for pumping and drawing the coals from the dip, but:

"As there are great objections to placing boilers and furnaces below ground both owing to the risk of fire and the inconvenience of the smoke I would recommend that the boiler be placed upon the surface and the steam carried down the pit. This would take away all risk of fire and the pipes being served with straw ropes and coated with plaster the loss of steam by condensation would be quite inconsiderable and there being an engine for winding and pumping upon the surface the boiler can be fed with water from it and the same fireman may attend both boilers."⁴³

On his return in 1845, Cadell found the engine working well, with little condensation in the pipes carrying the steam down the pit⁴⁴. The following year, he found the engine still in good order, and the waste steam was now condensed underground, so that the pipes for taking it to the surface had been removed. They had in any case been made useless by corrosion⁴⁵. In 1849 it was reported that the engine could scarcely keep down the water as well as draw the coal from a regular day's work. It was therefore considered time that another underground engine be installed, solely for pumping. This engine was to be "a horizontal condensing engine with pump-gearing, cylinder, etc. all fixed on one bed-plate", but there is no mention of where the boiler was to be located⁴⁶.

The building of additional engines such as this, together with the fact that engines of different types could be worked alongside one another, complicates an already complex innovation pattern, but in general the geographically widespread innovation of Newcomen engines in the second half of the Eighteenth Century was succeeded by the building of several engine types, including Newcomen's and Watt's, in the period 1800-1850. At this time, new sites were mainly in the Wemyss area and in the Dunfermline-Lochgelly 'belt', where engines of high-pressure, direct-acting designs began to be installed underground. By about 1900, large compound engines were being introduced, capable of lifting 12 or 1300 gallons (5,910 litres) per minute from 300 fathoms (549 metres) or more. This level of effectiveness was achieved by a number of detailed improvements in addition to those outlined above, and is an aspect of steam pumping which merits more detailed investigation.

In an attempt to assess objectively the improving effectiveness of steam pumping engines in Fife over the 160 years from 1755, eight characteristics may be examined. They are:

1. Depth of drainage achieved
2. Size of pumps employed
3. Diameter of the engine cylinder
4. Flow of water to be cleared
5. Number of hours per day spent pumping
6. Steam pressure employed
7. Horse-power of the engine
8. Rate of pumping in strokes per minute

The first problem encountered here is that the amount of information tends to vary from one characteristic to another. For example, we know the number of strokes per minute for only 11 pumping

engines in Fife, all of them dating from 1847 to 1900, while on the other hand, the depth drained is known for 26 engines, dated between 1754 and 1909. A second problem is that a characteristic cannot always be examined in isolation, since it may be closely related to other changes in steam power technology. A good example is how the high-pressure engine influenced the relationship between cylinder size and power output. Bearing these difficulties in mind, a look at each characteristic in turn can highlight some major developments in steam pumping innovation.

1. Depth of drainage. Figure 4.8 shows the depth of drainage achieved by 26 steam pumping engines ranging over a period of more than 150 years. Two major points emerge. First, the maximum depth began to increase quite markedly after about 1840, having changed little in the previous 80 years. This change may have been associated with the spread of the high-pressure engine about this time, but our sample is too small and our evidence too fragmentary for a definite relationship to be established. By the beginning of the Twentieth Century a range of depths from 100 to 333 fathoms (183 to 609 metres) had been established.

Second, steam pumping was employed throughout much of the period for comparatively shallow depths, up to 50 fathoms (91 metres), so although the steam engine made possible the exploitation of very deep seams it was not employed exclusively for this purpose.

However, the question of depth is complicated by the fact that some engines raised water not to the surface but to a day-level. For example, in 1814 a steam engine at Fordell delivered water into the day-level there⁴⁷, and a similar arrangement was to be found at Lochgelly in 1823⁴⁸. In Dunfermline during the early 1840s, lifting water to the day-levels "saves a great proportion of engine power by

not lifting the water to the surface."⁴⁹, but at Kellie in 1847 it seems the day-level was out of action so it was found necessary to pump the water to the surface⁵⁰.

Despite these cases, Fife pumping engines normally had to raise the water all the way to the surface. The greater depths to which pits could now be drained led Stephen to see the beginning of "a second phase of utilisation"⁵¹. Figure 4.8 would suggest that this second phase began about 1840.

2. Size of pumps. Figure 4.9 shows the pump diameters of the 28 instances where this figure is known for steam-driven column pumps. No particular trend is evident, except that the lack of examples around the end of the Nineteenth Century is perhaps a result of column pumps being superseded by more efficient and reliable ram and centrifugal types. We may suggest therefore that any increase in power from the new steam engines was expressed in depth drained rather than in the capacity of column pumps. An engine could, however, work a larger number of pumps, but this would find expression in the depth drained.

3. Diameter of engine cylinder. We know the cylinder size of 22 Fife pumping engines, from 1754 until 1909, and these are given in figure 4.7. The diagram seems to reflect three stages in the development of steam pumping. Stage one is the period up to about 1810, when the power of a Newcomen engine could be increased only by enlarging the piston area. Clerk's 1740 description of the Newcomen engine puts the cylinder size at 28 to 42 inches (71 to 107 cm) diameter⁵², so the 44-inch (112 cm) cylinder of the Dysart engine installed in 1755 and the 40 and 50-inch (102 and 127 cm) cylinders of the engines at Culross in 1793 seem fairly substantial for the time. Although the small sample must make our conclusion very tentative,

it seems that there may have been a modest increase in cylinder size in Eighteenth-century Fife.

Stage two is a period of smaller cylinders running from about 1810 until sometime after 1870. Smaller cylinders were made possible by the introduction of high-pressure steam, whose main advantage lay in its ability to deliver the same or a greater amount of work with a smaller piston. Clearly, the 100-inch (254 cm) cylinder installed at Leven in 1877 was an exception, being described by Cunningham as one of the largest in the country⁵³. It was certainly the largest in Fife, being matched only by the low-pressure cylinder of the compound engine installed at Lochore in 1902.

Stage three came at the end of the Nineteenth Century, when a number of very large compound engines were installed at Fife pits. We have the cylinder sizes of six engines, each with two cylinders, and these are given in the diagram. It is noteworthy that these are also the six deepest collieries recorded in figure 4.8. Although it is true that the shallowest of the six, at 100 fathoms (183 metres), is matched by an earlier winning of 1856, that case has a special explanation. Andrew Christie, the Lumphinnans tenant in 1856, had calculated on reaching the Lochgelly Splint seam at 80 fathoms (146 metres), and had erected an engine to drain that depth. Unfortunately, the Lumphinnans shaft had to go to over 100 fathoms (183 metres) before this seam was reached and as the engine was unable to pump the water at this depth, a more powerful one had to be ordered and appears to have been operational by 1856⁵⁴.

4. Flow of water to be cleared. Since the function of a pumping engine was to raise water, it seems reasonable to take the quantity pumped as one simple measure of an engine's effectiveness. However,

the "growth" of water with which an engine coped is not normally given in reports prior to about 1850, so we have only 16 cases over a period of some 70 years with which to assess any change. These are shown in figure 4.10. Too facile an interpretation is dangerous, for the "growth" of water was not always the amount successfully pumped, but taken with the other pumping characteristics under examination, these figures serve to emphasise again the impressive increase in pumping power which was manifested by about 1900.

5. Hours per day spent pumping. The number of hours in the 24 which an engine was required to work is not a fair yardstick for comparing engines, due to the great variety of both depth and water "growth". Indeed, working hours sometimes varied with the season, as at Kellie in 1854 where the engine was going "all the 24 hours in winter, and about 18 in summer, which is very heavy."⁵⁵

Earlier, at Halbeath, the Great Engine of 1812 was also working 18 hours, which Bald thought was "rather too much, where so much depends upon it being in good order, so as to have full command of the water."⁵⁶

On the other hand, a horizontal engine for both pumping and winding at the Milton Gas Coal near Westfield had to work only 4 hours per day in 1873⁵⁷. This was due to the lack of water to pump, rather than to a particularly powerful engine. In fact, an engine similar in most respects was installed on the incline of nearby Westfield shale workings about the same time and had to work the whole 24 hours in order to clear a "growth" of only 132 gallons (600 litres) per minute. Surprisingly, it was even found necessary to assist this engine at times when an old engine of 8-inch (20 cm) cylinder was set going at the pithead⁵⁸.

6. Steam pressure employed. After the innovation of high-pressure engines, the pressures normally employed in new engines would have risen significantly above the roughly atmospheric level of the Newcomen and Watt models. Unfortunately, we have inadequate data to properly test this assertion. All we can say by way of example is that the commonest pressure in the Dunfermline area by the 1840s was only 24 lbs per square inch.⁵⁹ This is despite the fact that Trevithick had in 1802 built at Coalbrookdale an experimental pumping engine working at a pressure of 145 lbs per square inch, and by 1830 Bald could report that underground engines at Newcastle worked at 30-50 lbs per square inch⁶⁰.

7. Horse-power. As with pressure, there is a shortage of data on the horse-power of steam pumping engines in Fife with 18 cases noted during a 26-year period following 1833. Horse-power ranges from 10 to 200, with a mean of nearly 69. We can note that although the 47 horse-power pump installed at Kilmux in 1835 was "a powerful pump for the times"⁶¹, only 10 years later the Queen pit at Halbeath could boast an engine of no less than 200 horse-power⁶². It seems unlikely that such a vast increase in such a short time was in any way typical, but Galloway implies that the Halbeath engine was not entirely out of the ordinary when he points out that the most powerful pumping engine in the North of England at this time was 300-350 horse-power and that among the "more powerful" engines of that area were four of about 250 horse-power each⁶³. Thus if the normal engine of the 1830s was rather less than 47 horse-power, and an engine of the 1840s was not abnormal at 200, we have here some confirmation of the view that about 1840 there was a significant shift in the trends of steam pumping at Fife pits.

8. Rate of pumping. Figure 4.11 illustrates again the lack of reliable data before the mid Nineteenth Century, and it would be dangerous to assert any firm trends. However, we may tentatively suggest that between about 1840 and 1900 there appears to have been a slowing down of the pumping rate in strokes per minute. This is probably the result of the tendency to build larger engines, since a large piston with a long stroke will make fewer strokes per minute than in a smaller engine. This is certainly true of the eight engines where both the length of stroke and rate of pumping are known, the 1854 engine at Kellie having a 3-foot (91 cm) stroke going 20 strokes per minute⁶⁴, and in 1900 the 12-foot (366 cm) strokes of Aitken and Kirkford going at only $3\frac{1}{2}$ and 4⁶⁵.

In summary, no one characteristic of the eight examined above can justify firm conclusions. Samples are too small, trends too vague and exceptions too numerous. Taken together, however, there are cases where reinforcement occurs, and we may perhaps suggest that the three periods identified in the diagram of cylinder sizes (figure 4.7) together with the proposal of a significant improvement in effectiveness about 1840, is about as near as we can get to a realistic analysis of the changes taking place in Fife's steam pumping technology between about 1750 and 1914.

While the massive pumping power of the later Nineteenth-century steam engines was their dominant feature, the main advantage conferred by the early engines was reliability rather than power. This reliability was not so much in the machinery itself, as in its freedom from the vicissitudes of the weather, unlike wind and water power.

The machinery itself was not immune to breakdown, but in keeping with the longevity of Fife's pioneer engine, still running at Dysart more than 60 years after its installation in 1754, there are few

examples of engines being out of service for any length of time. Nevertheless, at Lumphinnans No 1 Pit, the pumping engine had broken down on several occasions during 1858 and was an important factor in the reduced output for that year⁶⁶. In September 1867, production was again interrupted when the engine was stopped for repairs⁶⁷. In 1849, at Barncraig, Wemyss, the flywheel shaft of the underground engine actually broke while pumping. Although restarted after four days, a pump then broke down and delayed pumping a further two days⁶⁸.

Other evidence about "repairs" is sometimes a reference to improvements or maintenance work. For example, individual parts had sometimes to be renewed, as at Halbeath in 1812, when "not a day ought to be lost" in replacing the boiler⁶⁹. Five years later at Dysart the list of parts was more lengthy:

"The old engine being much worn out, would require immediately a new cylinder with cylinder bottom, piston valves, hand gear and plug road and a general repair of the woodwork inside of the house, the boiler, beam and pit-gear may be yet serviceable for many years."⁷⁰

Not only wear, but corrosion could be a problem. At Barncraig in 1849 the double-acting pumps were criticised as being very expensive to keep up owing to "bad water"⁷¹, and at Kellie in 1854 the water was described as "chemically bad, and destroys iron, particularly the boiler and pump barrels"⁷².

Human error, probably the result of lack of experience, also took its toll. The shortage of labour skilled in steam technology is remarked upon by Butt⁷³, and Bald emphasises the employment of English expertise⁷⁴. Three good examples of the "expertise" problem are found in Nineteenth-century Fife. First, in an undated valuation of Torry Colliery, probably about 1832, it is noted that:

"The engine was erected in a very superficial manner. It had no parallel motions, no cataract or other

means of regulating its working, and the spring beams not being fastened to the engine house the lever wall gave way and would very soon have come down altogether had means not been taken to secure the spring beams"⁷⁵

This engine had been bought second-hand and was apparently erected by a Rob Campbell for a fee of £35. It was repaired by Henry Cadell at the beginning of his unsatisfactory lease of Torry colliery in 1833⁷⁶, and he appears also in our second example when in 1845, he had to recommend various improvements to the running of the pumping engine at Wemyss Victoria pit. He felt that these changes should make the engine work more smoothly - "a matter of great importance to the duration of the engine"⁷⁷. Third, we have the error in running an engine at Comrie in 1861 at 16 strokes a minute with the result that the engine was "all racked to pieces"⁷⁸.

Despite these problems, Fife collieries seemed to suffer no great lack of expertise in steam technology, for although engines were erected in large numbers from the early Nineteenth century onwards, the problems and breakdowns recorded are relatively few in number. The price to be paid for this reliable and increasingly powerful ally came in two forms. First, the capital cost, and second, the high consumption of fuel at the pithead.

Several writers put the capital cost of an Eighteenth-century Newcomen engine at £1,000 - £1,500, and Duckham estimates £1,300 as about right, including an engine house⁷⁹. Most of the specific Fife figures are from the Nineteenth century, but are not always very detailed, ranging from the itemised estimates for fitting out Dunfermline colliery in 1825⁸⁰ to Kellie in 1849 which we are told had been fitted "at a considerable expence"⁸¹. The figures do suggest, however, that the cost of erecting a steam engine in the Nineteenth century was up to four times the Eighteenth-century cost. For

instance, at Dunfermline two estimates give amounts of £5,500, including pumps to 70 fathoms (128 metres), and £4,500, with pumps to 60 fathoms (110 metres). In each case, "all necessary apparatus" is included, and these sums appear to be about half the total cost of the fittings⁸². At Halbeath in 1845 the total fitting of the 84-fathom (154 metres) Queen pit cost £12,000 but we have no figure for the pumping engine itself⁸³.

To make any realistic generalisation about capital cost is impossible in a period when different types of engine were being erected. The Watt engine was evidently more expensive than both the Newcomen type and the high-pressure kind, but following Duckham's figure of £1,300 for a Newcomen engine, the 15 erected in Fife by 1800 would give a total investment by that date of some £19,500. Of course, only the larger scale enterprises could justify the employment of steam power, and Clerk of Penicuik was unable to erect one because his scale of operations was still too small to guarantee a return on the capital outlay⁸⁴. Early in the Nineteenth century, we find similar cases in Fife. At Outh in 1811 Bald remarks that a steam engine is out of the question⁸⁵, and at Dunfermline in 1825 it was recommended that no winning of the Splint coal be made by steam machinery due to the poor prospects of getting a return on the large amount of capital invested. At the very least, seven or eight years working would be required to even cover the costs of the fitting⁸⁶. On the other hand, at Fordell in 1820 we find that the savings on royalties and horses would be expected to repay the cost of a steam engine within one year⁸⁷. We must assume the engines were to be of substantially different capital costs.

A saving could be made if an engine was bought second-hand, and we have two cases of this in Fife. The Torry engine erected about

1832 had come from Clackmannanshire for a purchase price of £310⁸⁸, and in 1865 a pumping engine was bought for erection at Lumphinnans No 2 pit, but we do not know the price⁸⁹. However, we do have valuations for 7 different engines between 1833 and 1874, and they range from £100 to £400, with a mean of £235. Although a small sample from which to draw conclusions, these figures seem to imply a considerable depreciation, which could be a problem even when taken over a long period. For instance, the Kilmux engine, installed in 1835, was valued in 1860 at £280 but at only £100 in 1874, which was coincidentally the cost of the new boiler which the engine was said to require about that time⁹⁰. Such costs meant that steam pumping was an expensive business, and an example of how this affected one colliery is found in the Old Statistical Account for Ceres, where the value of the coalwork was said to be much diminished by the expense of a steam engine for drawing off the water⁹¹. By the time of the New Statistical Account, there was no coal worked "due to the expense of working and not from the want of coals"⁹². In Cameron parish, too, the expenses of working the coal had greatly increased by 1794, apparently due both to higher wages and to the employment of two steam engines⁹³. A reduced level of royalties is suggested for Balmule and Pitfirrane where the workings to be drained by steam in 1812⁹⁴, and a similar point is made for Fordell in 1820⁹⁵ and Balcormo in 1824⁹⁶. Clearly, steam pumping was seen as an additional expense on the tenant which justified a lightening of his burden of royalties. More serious was the situation at Durie after Landale's firm had taken a lease in 1854. Here, the cost of pumping was so great that the company could not obtain a margin of profit. Within a few years the field was abandoned and lay unworked until 1893, when the Fife Coal Company successfully accepted the challenge of pumping up to 1,600 gallons

(7274 litres) per minute⁹⁷.

Despite cases such as these, Bald's regularly-quoted view of 1808 was that the price of coals had only advanced 2d per ton in a period when the cost of labour and materials had doubled, an advantage he attributed to the steam engine alone⁹⁸. In other words, its overall effect was to keep down costs.

The cost of fuel was not a major issue on a coalfield, where the boilers could often be fed with unsaleable small coal. Nevertheless, large quantities of fuel were consumed in steam pumping and could sometimes prove a burden where it became a large proportion of the total output.

For example, at Kellie in 1854 the output of only 13 colliers had to support a pumping engine consuming over 2,000 tons (2032 tonnes) of coal per annum, a burden which Landale saw as being a heavy one⁹⁹. Soon afterwards, at Lumphinnans, a series of detailed figures running from 1852 to 1877 shows that the fuel used for pumping and winding varied annually, from less than 14% to about 23% of output. The latter figure was described as "about the largest in Scotland" in 1862, the year it was noted¹⁰⁰. However, 23% does not seem too bad when compared with a figure given by Jevons, quoting Mungall in 1842 that in some Lothian collieries as much as 40% of the total output was consumed in pumping¹⁰¹. Perhaps we should treat this figure with some scepticism.

Despite innovations designed to reduce fuel consumption, pumping and winding at Prathouse, Fordell, consumed nearly 8,400 tons (8534 tonnes) in 1869¹⁰², and two years later at Cowdenbeath, a figure of 11,000 tons (11176 tonnes) was current¹⁰³. These amounts are probably a reflection of the depths worked and the quantity

of water to be pumped, rather than showing any lack of efficiency in the engines. Watt's patent of 1769, after all, had been entitled "A method of lessening the consumption of steam, and consequently of fuel, in fire engines", and improvements in the Nineteenth century had further reduced the fuel consumption for work done. Fuel economy was not of great concern in Fife, however, and Cadell's view that "although at a colliery, I do not approve of coals being wasted"¹⁰⁴ was by no means a universal opinion. Coals were evidently wasted at Comrie in 1861 where inadequate machinery led to a greater fuel consumption than necessary¹⁰⁵, and at Lumphinnans in 1858 the pumping engine at No 1 pit was not sufficient for its work, so using an extra 3,000 tons of fuel per annum, equivalent to £2-300 in the year¹⁰⁶.

In general, new developments in steam technology were taken up in Fife for the depth achieved or power produced, rather than for economy of fuel. Indeed, the continued erection of Newcomen engines well into the Nineteenth century shows a considerable disregard for fuel costs, being as it was highly extravagant in fuel compared with its work output.

The general picture of Fife's steam pumping innovation is not a simple one, but may be summarised as follows. Fairly typical in the introduction and spread of Newcomen engines, Fife was early with the direct-acting engine and the resulting underground installations. High-pressure machines feature strongly in the mid Nineteenth century together with the single-acting engine of Watt's design, but double-acting engines and compounding failed to emerge until the great mining explosion of the late 1900s. Altogether, the engines were powerful and reliable with fuel economy of small consideration. What Clerk had called "one of the noblest inventions of this or the last age"¹⁰⁷ had lived up to the high expectations of its pioneers and had played a central role in Fife's developing coalfield.

Figure 4.1 NEWCOMEN'S ATMOSPHERIC ENGINE

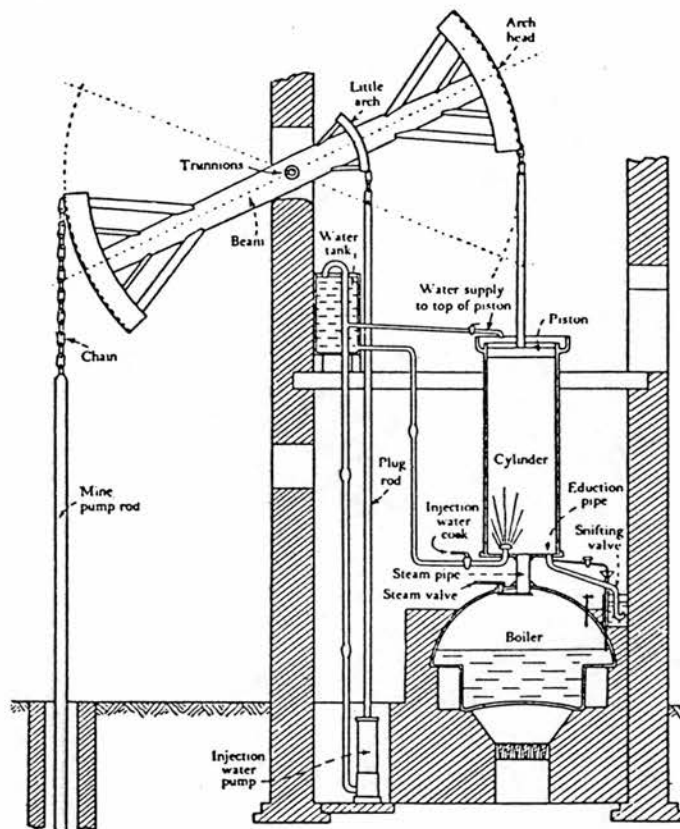


Figure 4.2 A DISUSED NEWCOMEN ENGINE, PHOTOGRAPHED IN 1886

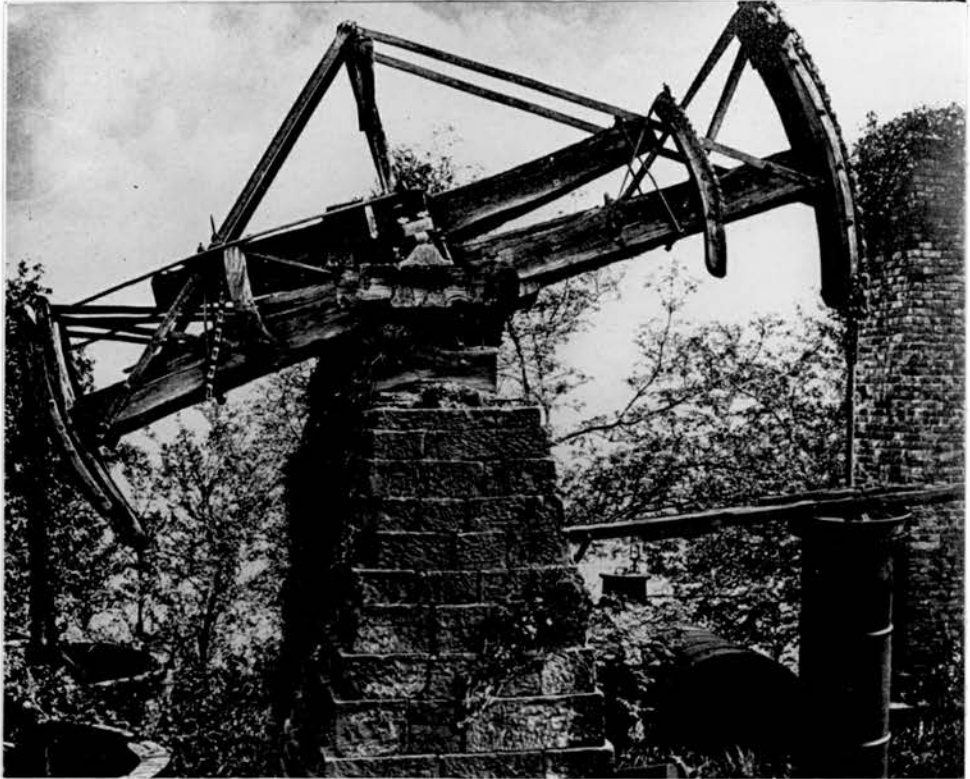


Figure 4.3
STEAM PUMPING ENGINES
ERECTED AT FIFE COLLIERIES BY 1800

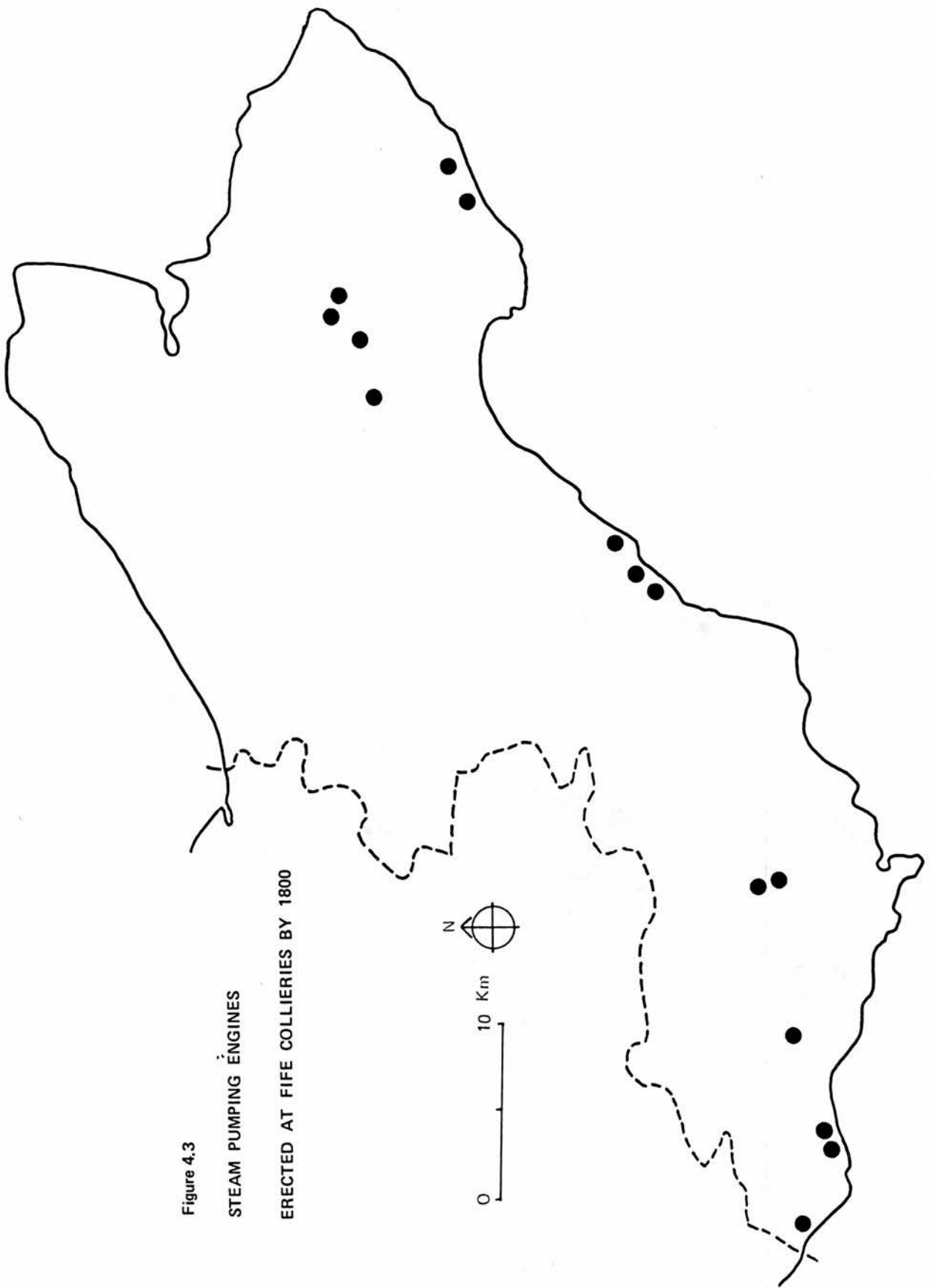


Figure 4.4 NEW STEAM PUMPING SITES (1755-1900)

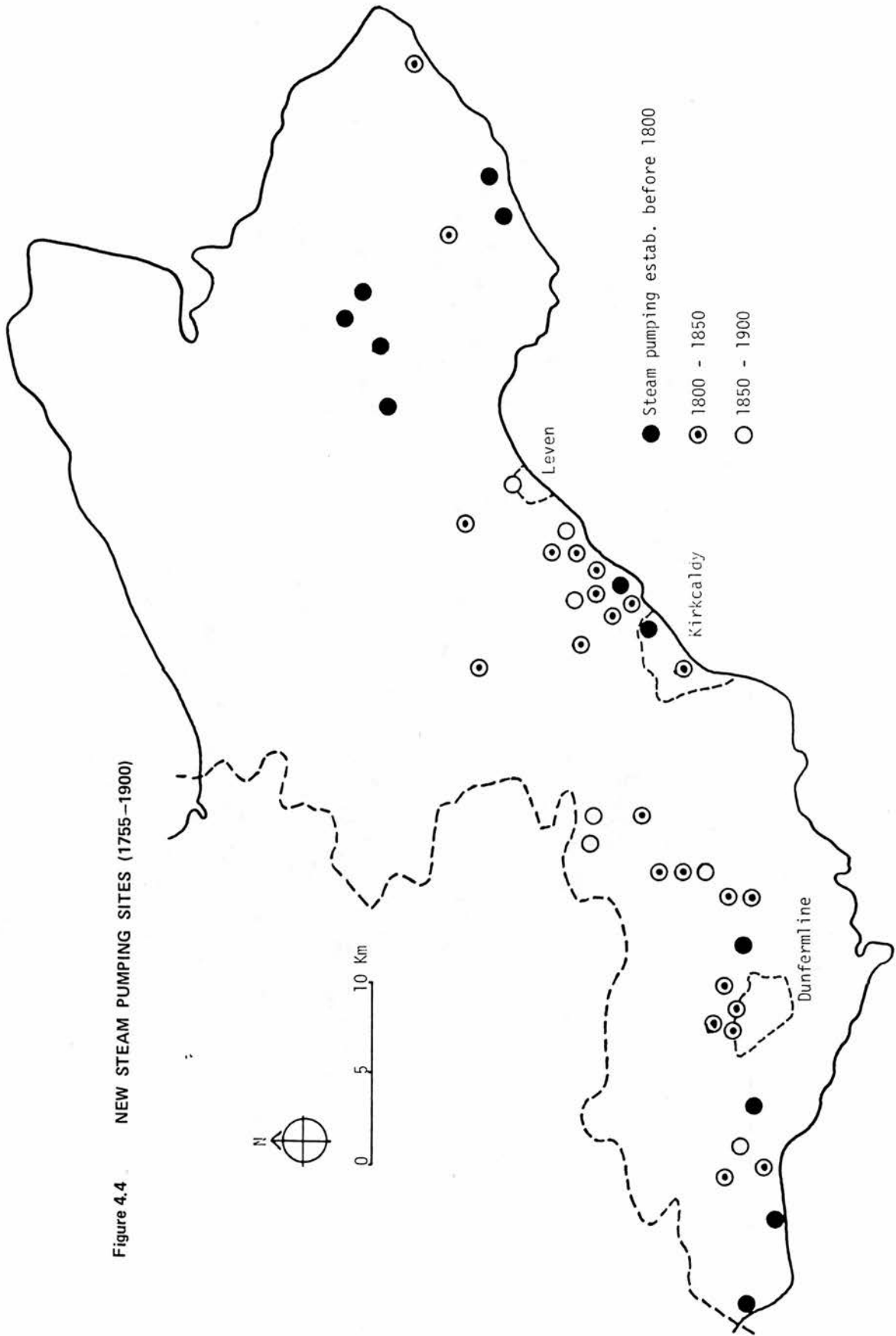


Figure 4.5 FIRST EVIDENCE OF STEAM PUMPING AT FIFE LOCATIONS
(1750-1910)

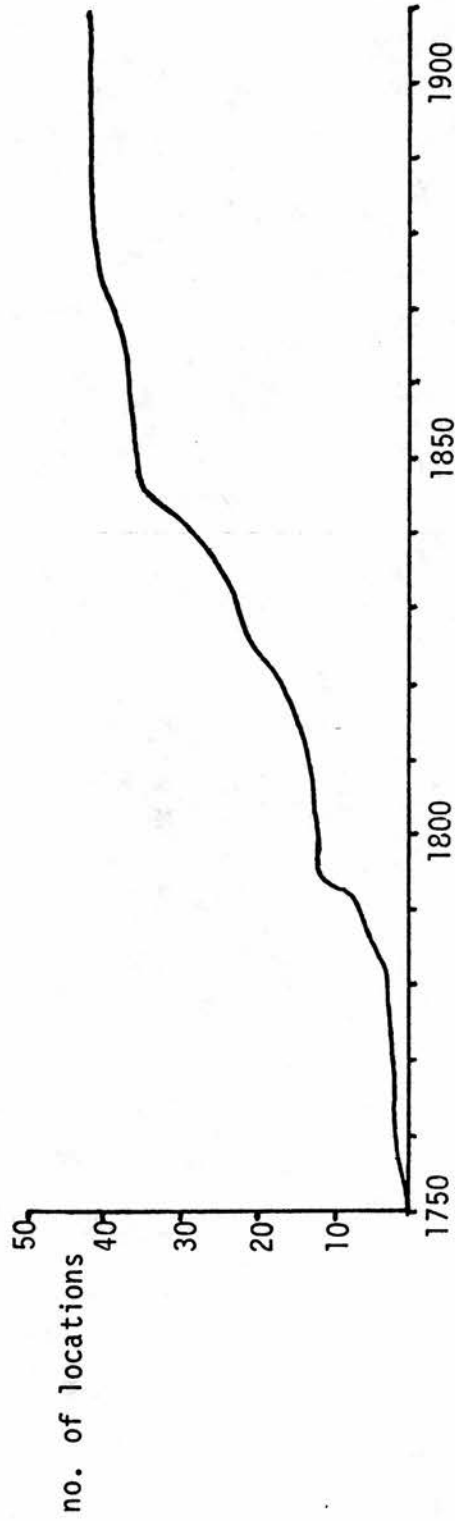
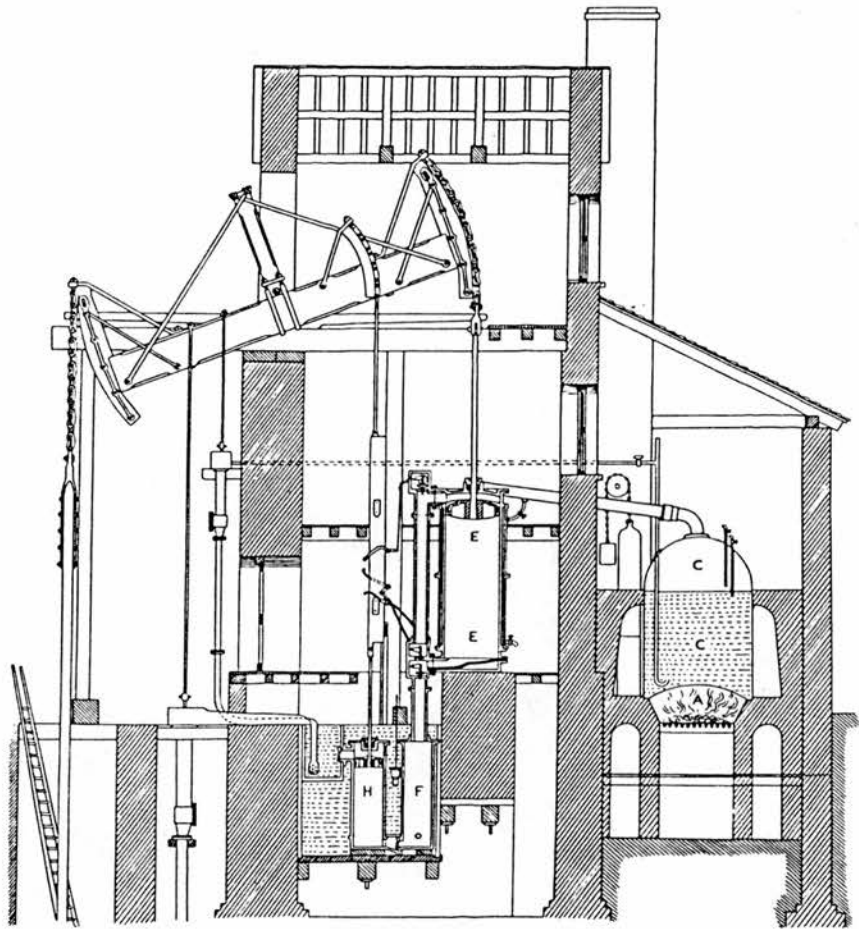
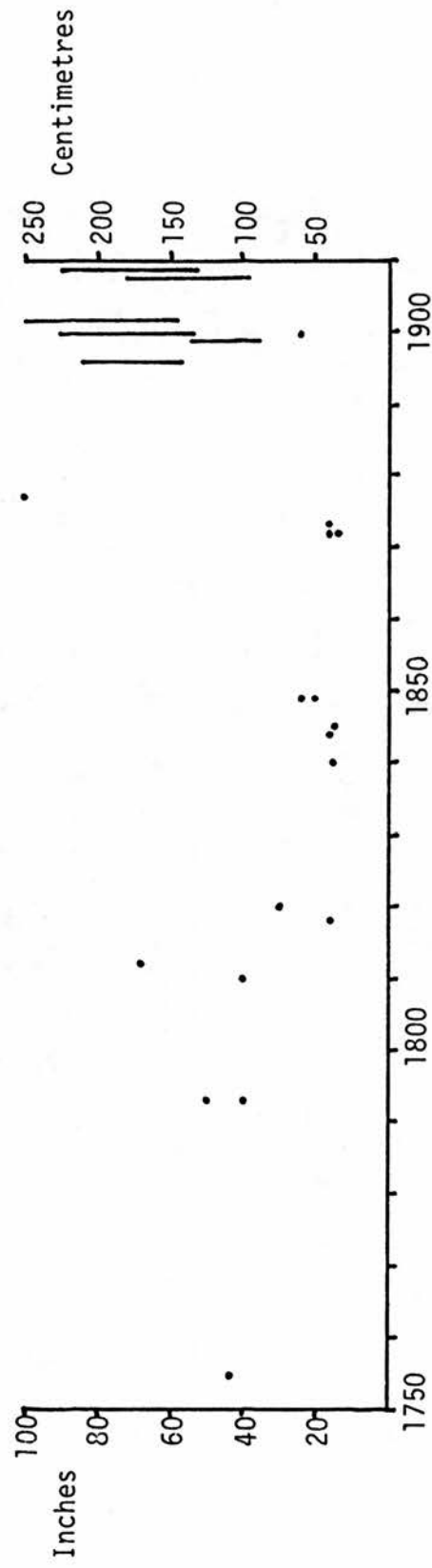


Figure 4.6 WATT'S SINGLE-ACTING ENGINE (1788)



The boiler C is placed in an outhouse, and the steam passes to the cylinder E, which is kept hot all the time by a separate steam jacket. F is the separate condenser and H an air-pump.

Figure 4.7 DIAMETER OF PUMPING ENGINE CYLINDERS IN FIFE (1750-1910)



(note: Compound engines are shown by a line joining the two cylinder dots)

Figure 4.8 DEPTH OF STEAM DRAINAGE IN FIFE (1750-1910)

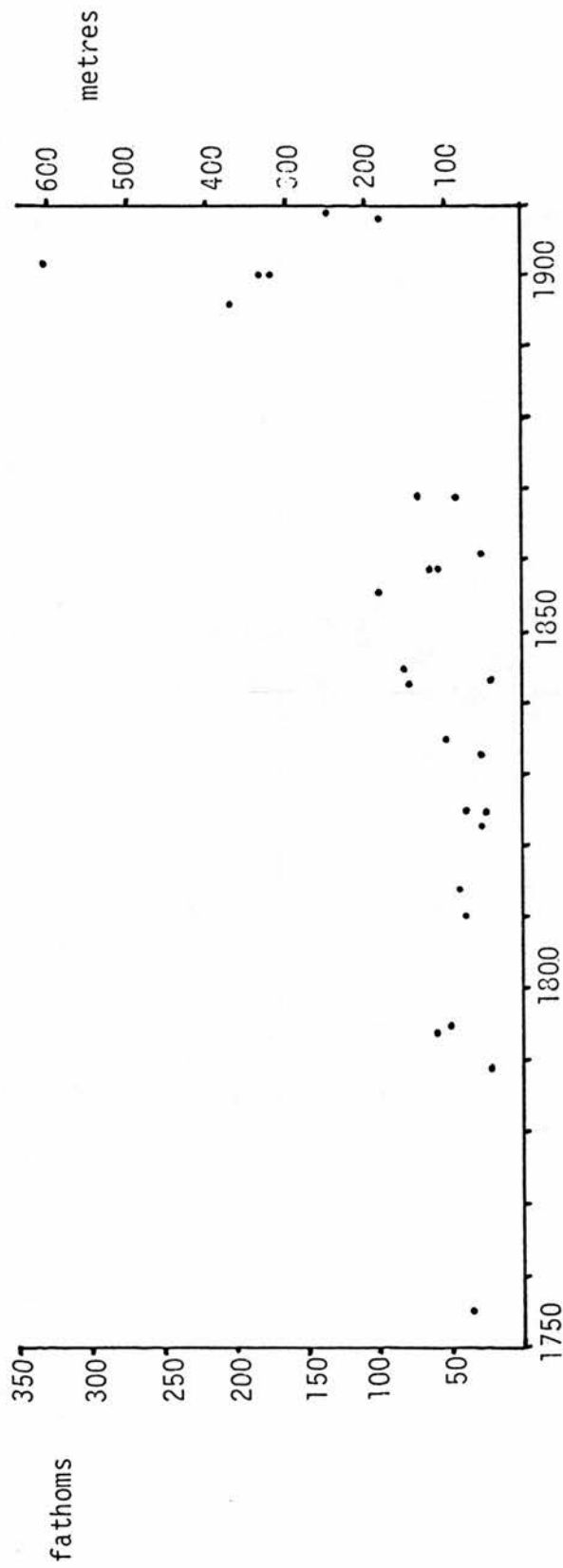


Figure 4.9 DIAMETER OF STEAM-DRIVEN PUMPS IN FIFE (1750-1910)

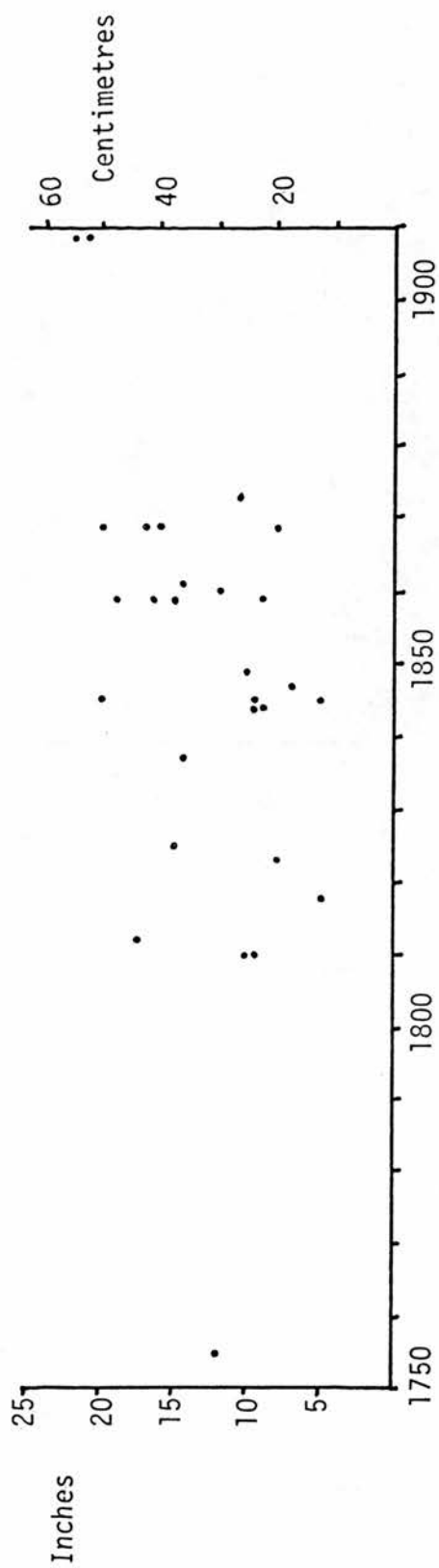


Figure 4.10

AMOUNT OF WATER TO BE PUMPED (1840-1910)

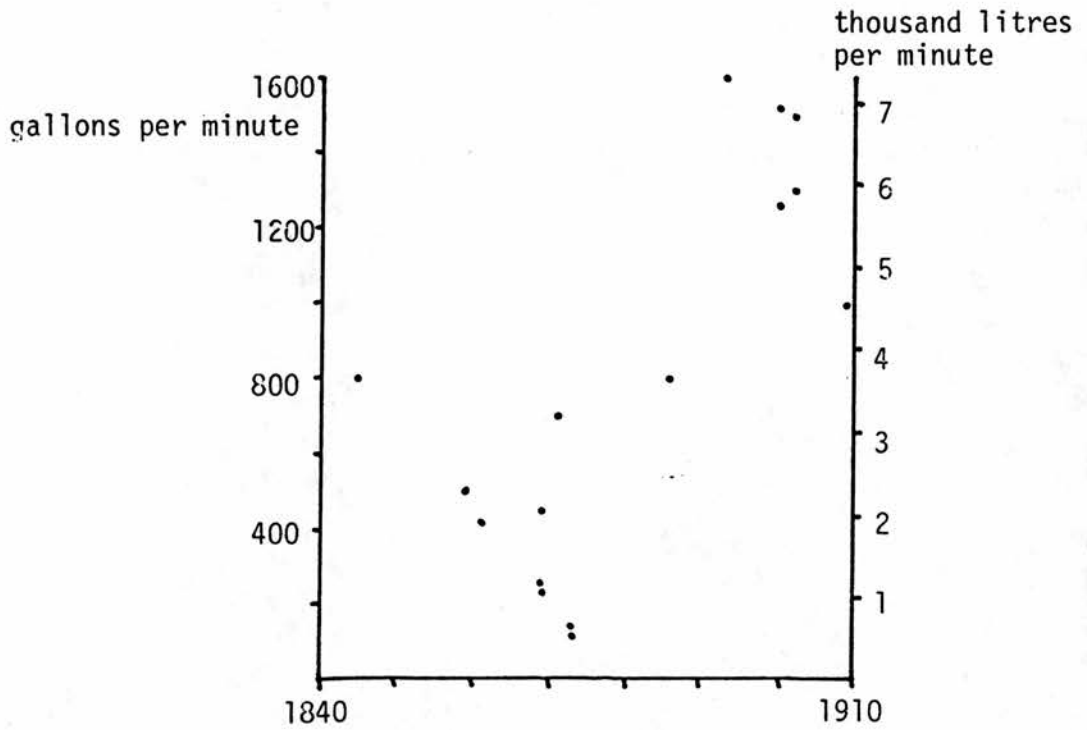
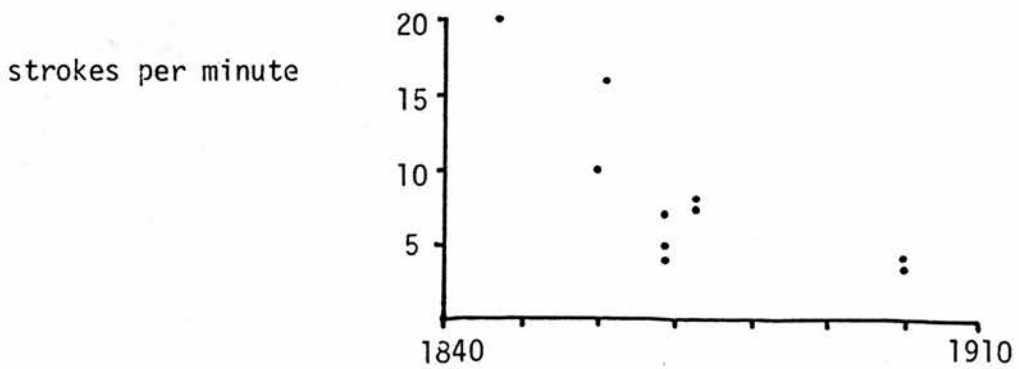


Figure 4.11

RATE OF PUMPING (1840-1910)



CHAPTER 5 - VENTILATION AND LIGHTING

Major improvements in underground ventilation and lighting were prompted by the presence of dangerous gases in coal mines, and although Fife was fortunate in avoiding the serious disasters found in other coalfields, the appearance from time to time of moderately small amounts of gas meant that the stimulus to innovation, though weak, was never entirely absent. In this context we will first examine developments in ventilation. We begin by looking at the nature of the problem in Fife, including the occurrence of gases and the question of how spontaneous combustion could be controlled. We will then consider methods of propelling air through the workings, including natural ventilation, its improvement by the use of furnaces and the introduction of giant fans in the late nineteenth century. Turning our attention to the route of the air current, we will examine the use of twin shafts and divided shafts before trying to assess the impact of the 'coursing' system on Fife pits. In lighting, we will consider the progression from the use of candles, through the spread of the safety lamp, to the innovation of electric lights in the late nineteenth and early twentieth centuries.

Of the three major gases, choke-damp, fire-damp and after-damp, only the first was widespread in the county. Choke-damp consisted chiefly of Carbon Dioxide and Nitrogen and by excluding Oxygen produced suffocation in its victims. Being denser than normal air it tended to settle on the floor of the workings and was easily detected by the extinction of a candle flame. This gas was particularly associated with level-free drainage where the more effective drying of the strata allowed the damp to escape through fissures normally sealed by water. Low barometric pressure, too, was

likely to result in the appearance of more choke-damp.

The earliest evidence of choke-damp in Fife comes soon after the mid seventeenth century, when 9 people at Dysart were killed by the gas¹. Fortunately, only a few other fatalities are recorded and Bald, indeed, goes so far as to suggest that a proportion of 'Carbonic Acid' in pit air was good for the miners:

"The workmen who breathe it every day are generally healthy, and it is reckoned a specific in some complaints, it being a common practice to send down children affected with the whooping cough to breathe in it."²

Despite this opinion, 'bad air' at Balbirnie was seen as a threat to good health, though how far choke-damp had a part in this is uncertain. Referring to the miners, the writer of the New Statistical Account remarks:

"What with the thin seams, bad air, and an unguarded use of ardent spirits, it is rare to find an old man among them."³

Although choke-damp remained a common hazard throughout the nineteenth century (some references to 'foul' or 'bad' air appear to be choke-damp), in no way can it be regarded as a major problem for the Fife miner. Despite its appearance at Dunfermline in 1844 where it 'in a greater or less extent pervades the whole coal workings'⁴, it was by this time possible to drive it out by effective ventilation, as at Lochgelly in 1842⁵. It could provide a local problem, however, such as that at Fordel in 1820, when Bald found the level pit so filled with foul air that he was unable to descend⁶, or at Cowdenbeath in early 1871 where the extraction of a small area of coal was problematical as a result of the quantity of choke-damp then emanating from subsided workings nearby⁷.

Gas was a problem even in 1901, when Hill of Beath Engine Pit lost several lives by gassing, and two miners died from the same cause

at Lumphinnans in 1906⁸. In 1912, progress at Valleyfield was slower than expected due to the large amounts discovered in some seams, but this may have been fire-damp rather than choke-damp⁹. Fire-damp ('Carburetted Hydrogen' or Methane) could form a highly explosive mixture with air, and was sometimes released during mining operations. Lighter than air, fire-damp tended to collect near the roof of a mine and an experienced miner could detect its presence by careful observation of his candle flame as he raised it from ground level. Fortunately, it was comparatively rare in Scottish mines and 'dread of the inflammable air' was one reason given in 1808 for the reluctance of Scottish colliers to move to England¹⁰. In 1835, Buddle could say of Scottish pits that one had to 'search for gas as a curiosity in them'¹¹, and in Fife particularly the early nineteenth century saw fire-damp found in only one very limited district. The Old Statistical Account had identified Rosebank colliery, Dunfermline as the only colliery in the parish in which inflammable air was to be found¹², and the report of the Children's Employment Commission of 1842 indicates that explosions had taken place at the nearby Wellwood and Blair collieries, in both cases without serious injury¹³.

By 1844, the Dunfermline pits still suffered from occasional incursions of fire-damp but had 'scarcely any' by 1859¹⁴. Towards the end of the nineteenth century, Holman was able to remark on the absence of fire-damp at Fordel¹⁵ and in 1901, Durland could smoke his pipe underground in the Aitken pit since there was not supposed to be any gas¹⁶. On the other hand, we have already mentioned the presence of gas, possibly fire-damp, at Valleyfield in 1912 and this was probably the agent responsible for the explosion which destroyed the nearby Preston Island colliery with the loss of several lives in the

early nineteenth century¹⁷. No other fatal gas explosions are known to have occurred in Fife, so the mid-century debate about the roles of gas and dust in mine explosions is of limited relevance to the county, as is the question of gunpowder's part in causing explosions. Chalmers does tell us that at Wellwood in 1859:

"The use of gunpowder by the colliers, in blasting the coal, vitiates the air very much more than before, when they relied chiefly on manual labour"¹⁸.

But precisely what is meant by 'vitiates' is not clear.

Due to the limited occurrence of fire-damp, after-damp (Carbon Monoxide - a poisonous end-product of incomplete combustion) does not feature as a problem in the Fife pits, except possibly as a result of the spontaneous combustion to which some collieries were susceptible and which provided a persistent problem for the mining engineer in the county.

Any attempt to measure accurately the scale of the spontaneous combustion problem in Fife is bound to fall at the hurdle of insufficient data. Although there is documentary evidence of fires from the mid sixteenth century onwards, we are often told simply that a number of outbreaks had taken place. For example, the Old Statistical Account states that Dysart coal was 'said to have had periodic eruptions once in 40 years'¹⁹, and we are told that at Drumcarro before 1842 the coal was frequently on fire²⁰. Nevertheless, the fact that we are here dealing with a long-term problem is very evident. Dysart had been on fire prior to 1555, and the 15 outbreaks in 9 Fife localities for which we have firm evidence carry on until 1909. In only two cases was the fire begun accidentally, the first being in 1741 when a limekiln set alight a seam at Dysart²¹, and the second about 1821 at Wemyss when coal rubbish was set on fire

after it fell on the flue of an underground engine²². However, these two locations also show evidence of spontaneous combustion, so the geographical distribution of underground fires is not distorted. The 9 locations are shown in fig. 5.1, and appear to lie in 3 groups. First, there are 3 in the West (Fordel, Cowdenbeath and Lochgelly). Second, a group of 4 appear in central Fife (Balgonie, Thornton, Wemyss and Dysart). Third, Largoward and Drumcarro are located in the East. It is tempting to link these 3 groups with the Lochgelly Splint and Parrot, Dysart Main and Chemiss seams, all 3 of which are known to be susceptible to spontaneous combustion, but such an explanation is rather too facile. Although the Western group all show ignition of the susceptible Lochgelly Splint and Parrot seam, the central group show more variation, with both Dysart Main and Chemiss seams catching fire. Also in this group, at Balgonie, we find the nine-foot seam mentioned in 1817 as a coal where spontaneous combustion had frequently taken place²³.

For the two Eastern locations we have no further information and we must recognise the fact that the geological conditions responsible for spontaneous combustion are incompletely reflected in the geographical distribution of actual occurrences. This may be because the susceptibility of the seam was not the only factor involved. Combustion was thought to result from the decomposition of Pyrites, and where this occurred alongside susceptible coal, the fire could develop to the extent that it merited comment in contemporary documents.

Consequently, the explanation for spontaneous combustion in Fife may lie other than in the geological field. There is evidence to suggest that the underground dumping of worthless small coal contributed in no small way to fire in the workings. For example,

Bald saw spontaneous combustion as being caused by the decomposition of Pyrites amongst the rubbish of the mine and felt that none of the small coal and rubbish should be allowed to remain in the wastes²⁴. He elsewhere points out that at Dysart 'this ignition takes place when the small coal is allowed to remain below ground in any considerable quantity'²⁵. At Largoward, too, it was the small coal underground which had often taken fire²⁶, and a Balgonie lease of 1849 refers to the drawing to the surface of 'heated rubbish' as the only cure for an underground fire²⁷. Thus geological conditions which produced a susceptibility to spontaneous combustion were often exacerbated by imprudent mining practice.

Underground fires were difficult to deal with and could have serious consequences for a colliery. At Drumcarro, for instance, it was found troublesome and expensive to control the frequent fires, and indeed the works had been stopped a number of years for this reason²⁸. At Balgonie before 1817, four pits had to be filled up when all attempts failed to extinguish the fire in their workings²⁹, and at Wemyss the fire of 1821 had put the colliery in a 'hazardous situation'³⁰. There was nevertheless a certain degree of agreement over what could be done to contain underground fires. There were four possible courses of action.

First, water could be thrown on to the fire. Second, drainage could be discontinued thus allowing the workings to flood. Third, the fire might be smothered by excluding air, and fourth, the burning matter could be drawn out and taken to the surface. The first solution appears to have met with little success. When it was tried at Wemyss in 1821, the men were unable to remain underground long enough to make it effective³¹, and by 1830 Bald had found another

reason for its lack of utility:

"The application of water has very little effect; for though it may in some degree extinguish the fire at that particular spot, it greatly promotes ignition amongst the adjoining rubbish, by bringing on a more rapid decomposition of the Pyrites"³².

Flooding the workings was the second option, but was seen as a last resort by Bald, who thought that any future draining of the workings would result in widespread ignition³³. Nevertheless, this was a technique which could be used successfully in some situations, such as at Dysart in the early 1790s³⁴. At Wemyss in 1821, however, the fire was too far to the rise of the engine dip-head level to permit flooding. The colliery would have been ruined³⁵.

Smothering the fire seems to have been successfully employed in some cases, and is described in 1830 as the remedy in common practice³⁶. Despite this, its use in Fife did not always produce a satisfactory result. At Dysart, for example, excluding the air had to be allied with a cessation of pumping, thus allowing the water to rise³⁷. At Balgonie in 1817, closing up the pits had no effect and four years later at Wemyss this method was found to be impracticable because proper access could not be obtained round the fire³⁸. Nevertheless, Williamson, referring to a fire at Cowdenbeath in 1871, thought that isolating the portion on fire was the only means of control which could be adopted. He had every hope that the work already done in this respect would ultimately extinguish the fire, but he recommended leaving the area closed up for at least six months³⁹. In South Staffs, a coal liable to spontaneous combustion was worked in such a way as to facilitate the exclusion of air from ignited areas⁴⁰, and Duckham suggests that spontaneous combustion in Scotland could not have been regarded as much of a menace, since no similar approach

was taken here⁴¹. However, the Chemiss seam in the Leven-Dysart area saw the workings divided into small panels which could be shut off quickly in the event of fire⁴². In Fife, the menace was real enough.

The fourth method, that of drawing the burning rubbish to the surface, was rather quicker and, apparently, very successful. Lord Wemyss used this technique to totally extinguish a fire in 1674⁴³. In 1821, again at Wemyss, this method was seen as the only practicable technique⁴⁴ and the Balgonie lease of 1849 was in no doubt about what should be done in the event of a spontaneous combustion:

"....it is certain there is no cure for this but drawing the heated rubbish to the surface, a tenant to be bound to remove all such from the wastes as soon as discovered..."⁴⁵

The fact that Gemmell, writing in 1909, could refer to the removal of burning coal to the surface as the best method yet found for dealing with spontaneous combustion⁴⁶, indicates that here was a problem which had not been solved by technological innovation, either because of its intractable nature or because it was not sufficiently widespread to merit the full force of the mining engineer's inventiveness. Most likely there was an element of both.

The lack of any serious gas problem in the Fife mines is reflected in what was almost a lethargic process of innovation for methods of improving air circulation. Only the three methods of natural, furnace and fan ventilation were of any significance in the county, and we know only a little about their distribution, probably because little was written about a problem which engineers saw as being of comparatively low priority.

At first, ventilation was accomplished by natural means, where a through-flow of air was generated by the wind or temperature

differences operating in shallow workings with more than one entrance. This was particularly the case with day-levels (adits), where air shafts were sunk at regular intervals and are now useful in tracing the routes of these drainage tunnels. The distribution of day-levels throughout Fife and the number of air shafts sunk on the levels of West Dunfermline give some indication of how valuable day-levels must have been in the ventilation of workings which they were built to drain. Even as late as 1842, David Butt, the overseer at Dysart colliery, could state:

"We have no other method of ventilating our pits than by leaving open unemployed shafts which are six in number, and two employed, leaving eight openings"⁴⁷.

This represented no advance whatever on Sinclair's description of ventilation in 1683, although he does point to its effectiveness:

"When there is a free passage between the bottom of the two sinks, you may observe the wind course down through the one, and running alongst under the ground, rise up thorow the other, even as water runs thorow a siphon. For this cause, when the coal-hewers have done with such a sink, they do not use to stop it, or close it up, but leaves it standing open, that the Air under ground may be kept under a perpetual motion and stirring, which to them is a great advantage. 'Tis very strange to see sometimes, how much Air, and how fresh it will be, even at a very great distance, namely four or five hundred pace, from the mouth of the sink."⁴⁸

In this respect, Fife seems to confirm Galloway's opinion that the ventilation of the bulk of collieries in Scotland was natural until the mid nineteenth century, when furnaces started to become more common⁴⁹.

Furnace ventilation, in which a fire or furnace was employed to promote circulation by heating the air in one ('upcast') shaft, was known from the mid seventeenth century, and although Clerk refers to the method in 1740⁵⁰, the earliest definite reference to it in connection with a Fife pit is in 1821 at Wemyss, where the owners were

advised to change the course of the air by 'hanging a fire' in the Stone pit so as to produce a current of fresh air in the Reservoir pit. However, this was part of a strategy for extinguishing the underground fire to which we have already referred and the ventilating furnace does not appear to have been meant as a permanent feature⁵¹. This view is confirmed by another proposal in 1846 to increase the flow of air in the Rough coal, Victoria pit at Wemyss by placing a small furnace at the pit-bottom and boarding up the pithead as high as possible to quicken the draught⁵². Furnace ventilating had already been introduced to Dunfermline parish by 1844, however, and we know that by 1859 all the major collieries there were very successfully ventilated using this method⁵³. It appears that furnace ventilation continued in use until the closing decades of the nineteenth century, but because there was no need to guard against fire-damp explosions, arrangements to conduct the mine air away from the flames were unnecessary in Fife, unlike some other coalfields.

The cost of fuel for furnaces was negligible, although in 1869 Wallace and Williamson were somewhat dismayed to find the Fordel furnaces burning Great Coal - 'the dearest and best coal that is raised' - instead of the colliery's most inferior fuel, which was the normal practice elsewhere⁵⁴. Figures for Lumphinnans No 1 pit in the 1860s show that during most of that decade the amount of coal consumed in ventilating furnaces and fire-lamps (braziers for light and heat) amounted to between 200 and 250 tons (203 - 254 tonnes) per annum. With an annual output often in excess of 20,000 tons (20,320 tonnes), ventilation furnaces must have consumed considerably less than 1% of production⁵⁵.

Furnaces in Fife seem to have been erected sometimes at the pit-bottom and sometimes on the surface. At Wemyss in 1846, for instance, the proposal was for a furnace at the pit-bottom⁵⁶, and at

Townhill the furnace operating in 1859 was at the bottom of No IV pit⁵⁷. At nearby Wellwood, though, the furnace was on the surface, and drew the current through an air-tight chamber from the closed-off shaft, whence the hot air and gases were vented through a 50-foot (15.25 m) chimney⁵⁸. At Cuttlehill, too, a ventilating furnace was located on the mouth of an air pit⁵⁹.

Furnaces were generally recognised in the nineteenth century as being effective ventilators, but the search for an alternative was prompted mainly by the need to avoid the danger of explosions. This meant that the waterfall and steam-jet were never seriously considered in Fife as possible replacements for the ventilating furnace, although the former is mentioned as a possible method of forcing air down a Wemyss pit in 1821⁶⁰. It was only when the powerful and reliable fans of the late nineteenth century became available that Fife coalmasters saw a viable alternative to furnace ventilation.

From about the middle of the nineteenth century ventilating fans began to displace the furnace in British collieries, despite the fact that some early fans were unable to match the performance of furnace ventilation. The idea wasn't new, of course, having been discussed by Agricola some 300 years previously, and more recently referred to by Bald in 1830, when he described 'fanners' wrought by hand⁶¹. Indeed, a fan had been installed at a colliery near Paisley in 1827⁶². Their greater safety, although a major advantage elsewhere, carried little weight in the largely methane-free mines of East Scotland and by 1873 there was only one fan of any sort in this part of the country⁶³. However, by the end of the century, several Fife pits were ventilated by fans. Four pits where the types of fan are

known are Mossbeath (Waddell fan, invented about 1864), Lumphinnans No 1 (Guibal fan, invented about 1859), Nellie (Capell fan, invented about 1883) and Aitken (Walker fan, invented in the late nineteenth century).

The amount of air circulated by these fans was considerable, with the seven-foot (2.13 m) Capell fan at the Nellie pit exhausting 150,000 cubic feet (4,245 cubic metres) per minute⁶⁴ and the sixteen-foot (4.88 m) Walker fan at the Aitken exhausting 100,000 cubic feet (2,830 cubic metres) per minute⁶⁵. At Mossbeath, the fifteen-foot (4.53 m) Waddell fan exhausted 50,000 cubic feet (1415 cubic metres) per minute⁶⁶. Although furnace ventilation could match these figures in some parts of Britain, the volume of air circulating in most coal mines during the mid nineteenth century was in the range 30-50,000 cubic feet (849 - 1415 cubic metres) per minute⁶⁷ and only 10,000 cubic feet (28.3 cubic m) was thought to be sufficient volume to ventilate virtually any colliery in Scotland at that time⁶⁸. However, the air propulsion is only part of the ventilation story, and we must now turn our attention to the question of the underground route taken by the current.

We have already seen that adits, driven primarily for drainage, had the incidental advantage of improving mine ventilation. Similarly, the ventilation benefits to be gained from a second pit were familiar to seventeenth-century miners. Bowman claims that Bruce's demonstration of through-ventilation by the use of two shafts at Culross was part of his 'most important contribution' to the development of the Scottish coal industry⁶⁹, and by 1676 Roger North could say that 'sinking another pit that the air may not stagnate is an infallible remedy' (for damps)⁷⁰. The Balgonie estimate by Francis Beaumont in 1785 includes the sum of £40 for 5 'pits for air',

each to be only $4\frac{1}{2}$ feet (1.37 m) wide⁷¹, and we have seen that the natural ventilation at Dysart in 1842 made use of no fewer than 8 shafts, only two of which were in use for mining operations. In 1862, the Coal Mines Regulation Act established the principle that each mine of more than 20 workers must possess at least two shafts or outlets at each seam, although this was enacted as a response to the Hartley Colliery disaster rather than as a means of improving underground air circulation. By this stage it had been recognised that bratticed (divided) shafts were a source of considerable danger, although they had been very popular in the early nineteenth century. Brattices had not only provided separate compartments for pumping and winding but gave both upcast and downcast routes for ventilation in the one shaft. This was clearly recognised by Clerk in 1740 when he saw the two divisions helping in the process of natural ventilation⁷². However, perhaps due to the pioneering work of Bruce, the two-shaft system seems to have been more popular in Fife, with the 65-fathom (118.8 m) Drumcarro pit the only one known to have been divided by a partition⁷³.

The underground route of the air appears to have been regulated with precision in only a few Fife collieries. Spedding's revolutionary 'air coursing' system was introduced in England about 1760 and this, together with Buddle's development of 'splitting the current' in the early nineteenth century, was vital in improving the safety record of the gassy pits in which they were employed. In Fife, however, there was not the loss of life or damage to property which were occasioned by huge explosions, so the impetus was lacking to invest in a complex system of doors and stoppings. In the 'coursing' system, partitions were used to thread the current through all the workings, and air doors had to be opened and shut to allow the

passage of trams or hutches. This task was performed by young children, designated 'Trappers', who worked long lonely hours, often in total darkness. An examination of the Fife evidence to the Children's Employment Commission of 1842 shows only three collieries (Elgin, Townhill and Capletrae) in which trappers appear. On the other hand, we are told that at Drumcarro, 'The air is coursed along the workings in the usual way.'⁷⁴, so it may be that while a majority of Fife pits used a coursing system of sorts, only a small minority had a system of such sophistication that trappers needed to be employed. It was recognised, however, that Longwall working made ventilation easier.

In Dunfermline parish in 1844, for instance, where longwall was used:

"there is greater security to the workers against the danger arising from fire-damp or choke-damp; for there are no vacant spaces allowed to remain where the impure gas may accumulate, as in those between the pillars, according to the Post and Stall plan, and whatever there may be of this gas is dispelled by a current of good air circulating from the pit bottom, where a fire is kept burning, or by communication with another pit, along the wall faces before the workers.'⁷⁵

Implied in this comment is the idea that vacant spaces in post and stall working would normally remain unventilated, and it seems reasonable to conclude that the system employed in Fife in the 1840s would have been that known as 'face airing' in which the current was directed merely to the working faces and not round all the vacant spaces in the pit as was the case in coursing. This would explain the Drumcarro comment as well as the relative absence of 'Trappers' in the evidence of 1842.

The lack of urgency which is apparent in ventilation improvement in Fife is found again in the advance of lighting methods, and for most of our period, candles provided the only illumination under-

ground. Small candles were preferred, with a small wick, since they provided a more distinct flame. They were normally of a size giving 20 to the lb (0.45 Kg), but in areas where fire-damp might be found, a thinner candle of 40-60 to the lb (0.45 Kg) was used. These latter were no thicker than a pencil. However, in areas of persistent choke-damp candles would not burn and on some occasions a phosphorescent glow was provided by hanging rotting fish in the working place. For example, this unpleasant practice was resorted to at Clunie in 1741 when it was found in driving a mine that although the air could be breathed safely, candles would not burn⁷⁶. At Lochgelly, too, sometime around 1800, it is recorded that a female hewer wrought where no light would burn, making use only of the reflection from fish heads⁷⁷.

Since fire-damp was scarce in the county, there was an absence of the tragic explosions which had elsewhere stimulated the development of the safety lamps by Clanny, Stevenson and, above all, Davy. The latter's invention of 1815, taken up very quickly in the fiery pits of Northern England, is mentioned at only two Fife collieries by 1842 - Blair and Wellwood, both West of Dunfermline⁷⁸. Although the Wellwood evidence says that Davy lamps were always used when necessary, this does not seem to have been very often. Chalmers' account of Wellwood, published in 1844, states that the safety lamp had 'at times, but not frequently' to be used⁷⁹. The habitual use of candles in these collieries would explain the minor explosions which seem to have taken place there in the early nineteenth century. On the other hand, the fact that safety lamps were never required at Fordell⁸⁰ is more typical of the Fife situation.

Oil or tallow lamps were probably substituted for candles in many pits during the third quarter of the nineteenth century, and in

1859 we have a comment regarding the Wellwood colliery which shows how much of an improvement could be achieved:

"a great improvement has now been effected by the burning of pure tallow for light, in an improved lamp constructed for the purpose, instead of fish-oils, frequently of bad quality, and emitting volumes of foul smoke in combustion. The tallow produces very little smoke, and the use of it is⁸¹ now compulsory by a regulation of the colliery."

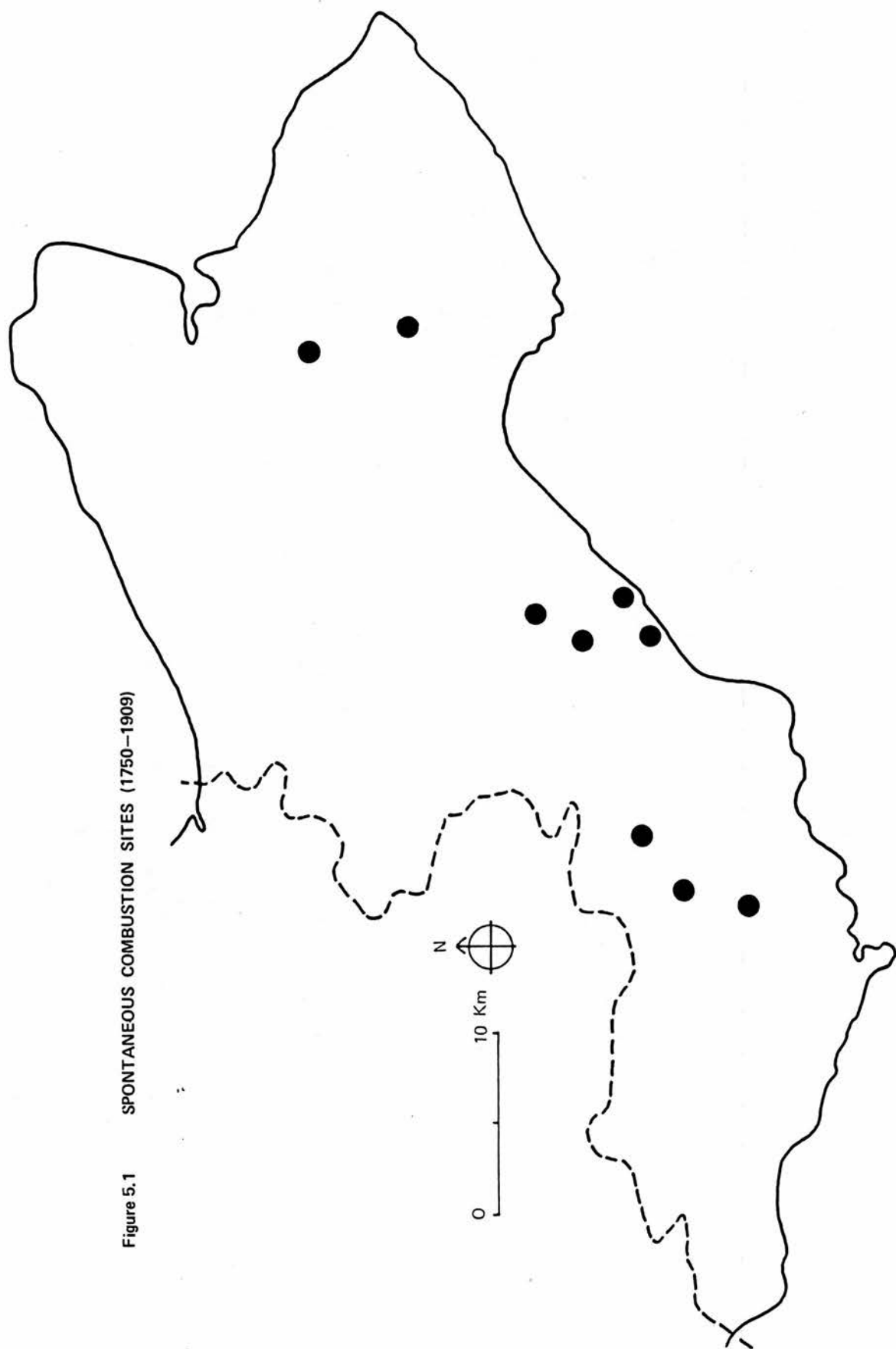
By the 1880s, the days of the tallow lamp were numbered, not by the various improved versions of the Davy lamp which by now had been developed, but by the introduction of electric lighting underground. One of the first underground installations was at a colliery near Glasgow in 1881, and the late nineteenth century saw the spread of electric lighting through the Fife pits. For example, 'several years' after 1884, Charles Carlow was responsible for having electric light installed at Kelty in both pithead and underground engine rooms⁸², and by 1900, electric lights were to be found in the Aitken, Nellie and Lumphinnans Nos 1 and 11 pits, with installation taking place at Dundonald in 1905, where Cunningham had recently been shown round by 'the flickering light of the small oil lamp'⁸³. Despite this success, the development of lightweight, portable electric lamps had to wait until about 1910 before their innovation became feasible. It has been estimated that the UK saw some 4,300 in use by 1911 and no fewer than 37,800 only two years later⁸⁴.

In summary, we have seen that the innovation process in ventilation and lighting has been less dramatic in Fife than in other coalfields and, within Fife, less dramatic than in other aspects of mining technology. This is mainly because the gas problem confronting the mining engineer was generally of low magnitude. An exception is spontaneous combustion, where a problem existed, but did not stimulate any significant innovation because it was not universal in Fife pits

and could be adequately dealt with by traditional methods.

Although laggardly in their introduction of ventilating furnaces, fans, safety lamps and air coursing, Fife pits seem to have been well forward in their use of electric lights. This may perhaps be explained by the 'stimulus-problem' of darkness exercising the mind of the entrepreneur, much as the gas problem had exercised the minds of the safety lamp innovators in England some 80 years before. Technological innovation in this context may be seen as the response to a particular problem or set of problems, and when the problem is of low priority, as was the case here, innovation is slow.

Figure 5.1 SPONTANEOUS COMBUSTION SITES (1750-1909)



CHAPTER 6 - WORKING THE COAL

'One of the most outstanding developments in the technical history of coal-mining' is how Ashton and Sykes describe the substitution of longwall working for the stoop and room method¹. This change took place in Fife over roughly the hundred years from 1770, and in order to appreciate the significance of this innovation for regional development in the county, it is first necessary to examine not only the nature of stoop and room working but also the advantages which led to its retention in some places well into the late nineteenth century. Secondly, we must look at variations on stoop and room working which prolonged its economic operation and consequently made less urgent the adoption of longwall. Third, we must examine the nature of longwall working itself, including its advantages and its influence on the introduction of other mining practices, such as the innovation of mechanical coal cutters. Only then will it be possible to reach a considered assessment of the significance of longwall innovation in the development of the Fife mining economy.

Stoop and room working

From earliest times, the method of working a seam was simply to take out part of the coal, leaving the remainder as support for the roof and superincumbent strata. Originally the room ('stall' or 'bord') was cut unsystematically, leaving stoops ('posts' or 'pillars') of irregular shape and size but by 1830, when Bald's well-known article appeared in the 'Edinburgh Encyclopaedia', workings were generally quite regular and Bald's sketch and description of the method together provide a clear picture of the technique (figure 6.1):

"A is the engine pit, B the bye-pit, or No 2 pit, CD the dip-head levels, always carried in advance of the rooms, E is the rise or crop mine, also carried in advance.

These mines not only open out the work for the miners in the bed of coal, but, by being in advance, give plenty of time for any operation which may be required, if these mines are obstructed by dikes or hitches. In this example the rooms or boards are wrought from the dip to the crop; the leading rooms, or those most in advance, are those on each side of the crop mine E; all the other rooms follow in succession, as represented in the figure; consequently as the rooms advance to the crop, additional rooms are begun at the dip-head level, towards C and D. If the coal is found to work better in a level course direction, then the leading rooms are next the dip-head level, and the other rooms follow in succession. In this manner the rooms are carried a cropping in the one case, till the coal is cropped out, or is no longer workable; and, in the other case, they are extended as far as the extremity of the dip-head level, which is cut off either by a dike or slip, or by the boundary of the coal-field².

The size and shape of the stoops was important since the workings were designed to extract as much coal as possible commensurate with the safety of the miners and the security and prosperity of the enterprise. Stoops in Fife were normally square or rectangular, although pillars 'of a diamond form' are described as having been in use for a long while at Dysart in 1817³. Of 27 workings whose pillar shapes are known, 13 were square, 13 rectangular and 1 was diamond (Table 6.1). It must be recognised that some of the sizes given in the table might simply have been recommendations or instructions which may not have been followed. For instance, the lease current at Baldrige in 1818 had specified pillars 18 feet by 12 feet but an inspection of the workings revealed that many were actually much smaller than this⁴. However, an analysis reveals that of the 31 locations listed in Table 6.1, 20 contain reports of actual sizes, 7 are instructions to tenants or mine officials, and only 4 are recommendations. It thus seems reasonable to suppose that the data produced is fairly accurate. Furthermore, we have no reason to believe that it is an unrepresentative sample.

An outstanding feature of the table is the extent to which room and stoop sizes are consistent over time, stoops showing somewhat greater variation than rooms. This is illustrated graphically in figures 6.2 and 6.3. In figure 6.2, it will be seen that 6 of the nineteenth-century pillars are over 100 square yards in area, and it may be that an examination of these will throw some light on the factors affecting pillar size.

The largest size is for a proposed stoop of some 200 square yards at Wemyss in 1845. These stoops were to be completely removed in a second working and were described as part of a 'Pannel Wall System'.⁵ Obviously, stoops designed for total extraction in a later working could be much larger than those which were to be left intact and this example suggests that the adoption of 'robbing the pillars' may account for much of the variety in nineteenth-century stoop sizes.

Stoops of 152 square yards were found at Dysart in 1817⁶ and were stipulated in a lease of that colliery in 1828⁷. The rooms were not wide enough at 16 feet to provide a satisfactory answer as to why such large stoops were needed, but these workings were in the Main seam, which produced a height of waste of 17 feet after being extracted in benches, so it seems that the thickness of the seam was a dominant influence on stoop size in this case.

The stoops of 100 square yards recommended for Wemyss Victoria pit in 1845 were a bid to win control over a crush (collapse) of the workings in the Rough seam. An earlier increase in stoop size from 15 feet square to 18 feet square had failed to achieve this, and it was thought that rows of larger stoops could alternate with rows of the smaller size.⁸

This aim of protecting the workings was not, however, the reason

behind the similar stoops at Cuttlehill in 1852⁹. Here, the Edinburgh, Perth and Dundee Railway Company insisted that its line at Cuttlehill be protected from subsidence damage by the leaving of three rows of pillars, 10 yards square, with the workings between them of only four yards width. The pillars were accurately described by John Williamson as being 'of larger dimensions than usual',¹⁰.

The sixth unusually large stoop identifiable in figure 6.2 is that at Kilmux in 1874, where it appears to be part of a variant on stoop and room working called 'room and rance',¹¹. The width of rooms, at 30 feet, is so abnormal and the stoops so long and narrow that the reporter's reference to 'rances' is almost certainly a pointer to this variant being employed. If so, it should not really appear in the figures which refer to traditional stoop and room working. However, its inclusion serves very well to reinforce the argument that room and stoop sizes varied only when some significant alteration was made to normal stoop and room techniques.

This brief look at some examples thus highlights the fact that the nature of the seam, the security of the workings and the avoidance of subsidence were all involved in determining stoop size. On the other hand, depth appears to be less important than we might expect. For example, there is no evident relationship between depth and stoop size in the three Fordell seams noted in 1869¹², and on the whole colliery reports fail to mention depth as a factor. Only in Thornton in 1840 did an inspection reveal 'the width of the rooms contracting on nearing the crop, or where the roof is insecure',¹³.

The figures given in Table 6.1 mostly refer to normal dimensions of the workings concerned, but it was common to leave particularly large pillars where the protection of workings or surface

was especially important. Two examples of this have already been noted at Wemyss Victoria pit and at Cuttlehill. An earlier example is that of Balbirnie in 1814, where the Main coal was reported to have 'very large pillars and chains of wall' left near pit bottoms, roads and air courses¹⁴.

Where the roof was bad and liable to fall, an alternative to larger pillars was the use of timber props. Langton identifies this method at Haydock, Lancashire in 1714 where the cost of extra timber was 'repaid double by the quantities gotten out of those places supported by Propps where wee used to leave Pillars'¹⁵.

The practice was disapproved of by Clerk of Penicuik who had found wide East Lothian workings propped up by timber and warned that in time the timber would rot and roof falls result¹⁶, but it was primarily for safety reasons that 'timber struts' were employed in certain areas of the Cluny, Fife pits in 1747¹⁷.

By the mid nineteenth century, however, props were a more significant accessory to stoop and room working in that a second working was becoming commonplace, with props used to secure the roof during stoop removal. 'Special Rules' at Elgin Colliery in 1856 make it clear that the collier was responsible for props selected from propwood provided by the employer. Furthermore:

"When employed to return upon and remove coal-stoops left in any coal-seam, colliers shall be bound to prop and secure the roof and strata around each stoop, before commencing to cut or remove the same"¹⁸.

Proportion of coal extracted

The complete removal of stoops was important in that it represented a variant on traditional stoop and room working but it was also significant in that it was an attempt to overcome the major failing of stoop and room, namely the sterilisation of up to half the

coal in permanent underground pillars. Figure 6.4 shows the proportion of coal left in pillars for a sample of stoop and room workings. Since the proportion left underground will depend on the size of stoops and rooms, it is not surprising that the long term consistency evident in figures 6.2 and 6.3 should appear again in figure 6.4. It seems, however, that nineteenth century workings left a bit less coal underground, with about a quarter to a third sterilised while eighteenth century figures suggest a proportion of about a half. For example, 'J C' recorded in 1708:

"there is not quite half of the coals taken out
of the ground which lies there"¹⁹.

and it is roughly this proportion which is implied in the dimensions of workings given for the Rothes pits about 1740²⁰ and confirmed by Renwick's recommended figures for Balgonie in 1787²¹. By 1808, however, Bald was able to state that pillars amounted to a third of the whole field²², and this is the first of a series of nineteenth-century comments which show the greater proportion extracted in stoop and room workings at that time. It seems that there was a 'break' around 1800 when traditional stoop and room working became more effective in terms of coal extracted. If this was indeed the case, either pillars became smaller or there were fewer of them, thus providing wider rooms, but figures 6.2 and 6.3 show no such 'break'. This suggests that the feature observed in figure 6.4 is more apparent than real, in which case one might suspect the eighteenth-century figures of unreliability. On the other hand, the eighteenth-century proportion of about half is confirmed by Bremner²³ and by Ashton and Sykes²⁴.

It seems there are two questions here. First, is the 'break' real or apparent? Second, if it is real, how may it be reconciled with the fact that there seems to be no significant 'break' in stoop

or room sizes about 1800? First, it is felt that the evidence justifies a real difference between eighteenth and nineteenth centuries. Our second question may be answered as follows.

We shall see later that 'robbing the pillars' became common in nineteenth-century Fife. Thus the proportion eventually left as pillars would fall, as shown in figure 6.4. However, colliery reports might well continue to give the dimensions of stoops and rooms as for the first working - dimensions which would have changed little from 100 years previously. Thus the proportion left underground could decrease without recording changes in the sizes of workings. This line of argument implies two things.

First, it implies that pillar sizes, if anything, would have increased slightly in the nineteenth century in the knowledge that they would be removed later. Figure 6.2 confirms this. Second, it implies that 'robbing' became a normal and accepted part of stoop and room technique in nineteenth-century Fife. We shall see later that this was indeed the case.

In general, the information given in figure 6.4 reflects Bald's comment in 1814 when in a reference to Balbirnie colliery, he claimed that a quarter of the coal was 'as little as could have been left in a post and stall work'²⁵. Certainly, the previous year had seen a valuation of Thornton colliery assuming that one third of the coal would be left in pillars²⁶. By 1830, however, Bald was able to make the more general claim that the amount of coal wrought varied from four-fifths to two-thirds (thus leaving one fifth to one third in pillars) where the depth did not exceed 70 fathoms. This remark finds an exact parallel in Chalmers' description of collieries in the Dunfermline area in 1844, where he refers to Townhill, Halbeath and Cuttlehill as follows:

"in some cases, two-thirds of the coal are wrought, and one third is left in pillars....where the roof is considered strong, three-fourths and in some even four-fifths, are taken out"²⁷

This again indicates how the nature of the roof could influence mining practice, with a poorer roof requiring more coal left in for support. Leaving stronger pillars for the security of the workings as a whole also had a price to pay in terms of lost coal. For example, at Wemyss in 1845 a new stoop and room system was cautiously proposed as a counter to a possible collapse of the workings. The proposal involved leaving one third in pillars, rather than one fourth and envisaged a system using wider workings and larger stoops. The roof was to be secured by stone buildings 'to support the low side of the road'²⁸ and propwood. By 1849, however, we read that large pillars, amounting to three-sevenths of the coal, were being left on account of a crush having affected pillars 'much weaker than at present, scarcely one third of the coal being left'²⁹. Clearly, leaving one third in pillars had not been enough. On the other hand, leaving only a quarter was perfectly adequate at Methil only a few years later³⁰. On the whole, such local variation depended largely on geological conditions, and does not detract from the overall consistency of the county-wide picture. In other words, the employment of the stoop and room method produced a general consistency in proportion extracted which was varied a little depending on local geology. The method was unable to extract a greater proportion of coal when employed in the 1870s (eg at Lassodie and Kilmux) than in 1814 at Balbirnie. Nevertheless, we have identified an improvement over eighteenth-century figures and we have suggested that the difference might be due to the incorporation of 'robbing the pillars' into normal stoop and room practice. It is thus appropriate that we begin our

examination of stoop and room variants with a look at this process.

'ROBBING' THE PILLARS

The practice was obviously familiar to Scots colliers before 1750, since Clerk of Penicuik appears to have sanctioned it in 1725³¹ and comments in his Dissertation of 1740:

"Care must be taken not to suffer coaliers to impair these pillars, as they commonly do for their own advantage, till such time as the coalfield, or all that is necessary or can be got of it, be entirely exhausted"³².

This caution of 1740 is reflected in the Rothes, Fife pits about the same date, when robbing was normally carried out only 'where the roof will be sufficient when the coal is taken down'³³.

Clearly, what Buxton has called 'the constant temptation to whittle away' was recognised at the beginning of our period³⁴, but in the nineteenth century it became a more formalised procedure. In September 1814, for instance, Bald found some men employed in working the pillars of Main coal in Millbank pit, Balbirnie. Although he did not object to the working of large pillars, he advised that the process should begin at the greatest distance from the pit bottom and that the pillars around the pit bottom should be left untouched to keep the shaft safe³⁵. Bald again described the technique in 1830, saying that pillars would be left larger than necessary and then removed in a second working which progressed back towards the pit bottom using props to support the roof³⁶.

That the techniques of 'robbing' were employed widely in Fife is confirmed by a variety of sources. For example, we find a specific prohibition in a Dysart tack of 1828 that 'no pillar shall be pared'³⁷. The need for this to be spelled out implies that 'paring' was otherwise to be expected in the area at that time. A similar point may be made about Drumnaird in 1874 which specifically excludes pillars from an estimate of colliery reserves because the

lease then current did not provide the power to work them. The implication is that pillars would normally have counted as reserves. In mid century, the practice of robbing was widespread. At Kellie in the East we hear that during 1854 the pit was nearly finished 'except for reducing the pillars',³⁸ and at Methil about the same time pillars were successfully cut through with no sign of even a partial collapse³⁹. In the Kellie case, however, it appears that the method employed may have been 'Room and Rance', in which event the removal of pillars was more likely to be employed (see below). At Lochgelly, in central Fife, pillars were normally robbed as part of stoop and room working until about 1880, when longwall became the dominant form in that colliery⁴⁰, and we have already noted the practice in Dunfermline, referred to in Elgin's 'Special Rules',⁴¹.

Consequently we had in Fife a nineteenth-century situation which mirrored almost exactly Bremner's 1869 description of workings at Arniston, Midlothian, where 'pillars are allowed to remain until the limit of the seam is reached, when the miners turn back and work away the pillars, using wood props to prevent the roof from falling',⁴².

Robbing the pillars had thus moved on from being a piecemeal and often unofficial practice in eighteenth-century mines, to a more systematic, wholesale and generally recognised method of improving output in the nineteenth. In this respect it was commonly employed in the stoop and room variant known as 'room and rance'.

ROOM AND RANCE

In room and rance working, the rooms were normally wider than in ordinary stoop and room. Roofs were occasionally supported by wood props or by stone buildings using extracted rubbish and also by long narrow pillars or 'walls' of coal which were sometimes extracted in a movement back to the pit bottom. Galloway provides a short

description of the method⁴³ and suggests that it was originally developed to meet the needs of thin seams or those containing bands of stone where a quantity of rubbish had to be stowed underground. Despite this apparent advantage, room and rance seems to have played only a minor part in delaying the innovation of longwall working. However, varieties of it do appear to have been used in East Fife throughout much of the nineteenth century, and an examination of the techniques used at Balbirnie, Wemyss, Kellie and Kilmux from 1814 to 1874 is instructive.

At Balbirnie in 1814, a reference to 'long walls' is made as follows:

"In one place, however, a number of rooms were wrought in long walls, that is, a pillar and room of nine feet each without thirlings; so that upon the rooms gaining the utmost point proposed, the colliers turned upon the chains of wall left and brought every inch of coal out"⁴⁴

This was employed in the same seam as traditional stoop and room and is clearly different from the 'long walls in the Shropshire style' operating in the Two Feet seam. Although lacking the wide rooms and stone supports of room and rance as described by Galloway, this variation seems to be an early example of the method by which 'all the coal was saved',⁴⁵.

Some 30 years later, in 1845, we find the Wood coal at Wemyss being wrought on a 'Chain Wall' system:

"the rooms being 20 feet wide and the pillars 15 feet thick and cut through only at long intervals, height is taken out of the roof on the rise side of each place to make the roads 4½ feet high, and the red from this, is stowed in the low side of the road, so as to be a support to the roof, this system appears to answer the working of this seam well..."⁴⁶

Here we have wide workings supported by waste material and very long pillars. There is no indication that pillars were removed, but

the method must stand as a form of room and rance. Another variation was operated in the Parrot seam at the same time and place, where the method was:

"...to drive rooms of 13 feet wide, leaving at first pillars of 27 feet thick, through which afterwards rooms of 11 feet wide are driven, leaving the ultimate pillars 8 feet thick, the roads are carried forward in the 13 foot rooms, a row of props being set along the centre of each of these to support the roof."⁴⁷

Since these props were meant to be permanent, it was advised that they be charred to prevent rotting.

At Kellie 9 years later the term 'room and rance' is actually used in a reference to the pit which we have already noted as being nearly worked out except for the pillars. Here, the coal was 'worked by long pillars, 9 feet thick and rooms 13 feet wide, or room and rance, holed occasionally for air....'⁴⁸

This last feature was also found in our final example, that of Kilmux in 1874, where:

"The workings are very wide, 30 feet on an average, and the rances about 15 feet broad through which 15 foot openings are cut for the purpose of ventilation every 22 yards of so."⁴⁹

Generally, although we may identify considerable variety in room and rance methods there appear to be no major advantages over ordinary stoop and room working, especially with robbed pillars. Only where rances were entirely removed, as at Balbirnie and Kellie, could we expect a significant increase in the proportion of coal extracted. It may be the case that room and rance working made easier the subsequent removal of pillars, but there is no evidence that thin or stoney seams were made more economic or that other problems (eg ventilation) were ameliorated.

In this situation, room and rance working was not a sufficiently profitable innovation to secure widespread acceptance in the coalfield, and the same might be said of Panel working, despite the demonstrably

greater advantages it enjoyed.

PANEL WORKING

Panel working was originally introduced into Wallsend colliery, Newcastle, by John Buddle in 1810⁵⁰. By this method the seam was divided into districts or panels, separated from one another by strong walls of coal, solid except for access and ventilation roads. The coal within the panel was wrought on a regular stoop and room plan but with large pillars. These were later removed with the temporary aid of propwood and the strata eventually allowed to settle into the goaff or waste. Where panel walls could be wrought progressively backwards towards the pit bottom, almost all the coal could be extracted, an advantage which, according to Galloway, could be realised without inducing creep. Furthermore, it was possible to take out the pillars within the panel as soon as the initial working of that area was complete, there being no need to wait until the entire winning had been exploited.

Despite these advantages, panel working did not appear in Fife until mid nineteenth century. Writing in 1830, Bald claimed the method was then in the process of being adopted by mining engineers in the North of England, thus implying that it was still to find its way into the Scottish fields⁵¹. It was not until 1845 that we find Henry Cadell recommending the adoption of a 'Panel Wall System' at Wemyss, but while Bald refers to a panel of from 8 to 12 acres, Cadell's proposal was for a district of some 6 acres⁵². In addition, Bald described panel walls 40-50 yards thick but Cadell makes no mention of them. In fact, Cadell's proposal seems like a sort of 'half way house' between stoop and room working on the one hand, and panel on the other. It does appear to have been put into effect, though, for we are told the following year that workings in the Rough

coal, Victoria pit, were to be on the Pannel Wall mode⁵³.

In 1871, we find the Panel system being recommended to replace stoop and room in the Lochgelly Splint and Parrot seam at Cowdenbeath⁵⁴. Panel was also recommended instead of the usual Longwall in the 5 foot seam due to that coal being 'of so soft a description'. The exact wording of this last proposal is interesting, since the manuscript originally proposed stoop and room which had then been crossed out and replaced by Panel⁵⁵. This may mean nothing, but it could imply that panel working was in this case only marginally better than stoop and room. It certainly seems that both stoop and room and panel working were more suitable here than the longwall employed in this seam elsewhere in the district. Such a mixture of working methods is not untypical in mid nineteenth-century Fife and shows that the gradual replacement of stoop and room by longwall was by no means a simple process.

In 1872, panel working was specified in a Foulford lease⁵⁶. Panels were to be 6 or 7 acres in extent and were to be surrounded by pillars 'not less than 22 yards broad by 33 yards long....rooms and openings in the barriers to be not more than 12 feet wide.....'. These dimensions were considerably smaller than Bald's generalised figures of some 40 years before, although the size of panel accords with that in the Wemyss example of 1845.

In general, panel working may be seen as an advantageous development of stoop and room, involving almost total removal of the coal in a second working, and displaying specific benefits of security and ease of ventilation. Despite this, it came too late in Fife and could not compete with longwall, already well established as the principal challenger to traditional stoop and room.

LONGWALL

The longwall system allowed the entire coal to be excavated in one working, and for clarity of description it is difficult to improve on the eighteenth-century outline quoted by Duckham:

"...the whole breast of coal is heaved down and carried off, nothing being left except the rubbish produced in the course of working, and which is laid up in regular heaps, reaching almost as high as the roof. At the place where the colliers are working, the roof is supported by 2 or 3 rows of wooden pillars, which are brought forward as the colliers advance; and upon removing the (wooden) pillars, the roof behind subsides gradually, till the rubbish, upon which it rests becomes sufficiently solid to resist the incumbent pressure"⁵⁷.

Bald's illustration of 1830 is reproduced as figure 6.5. He stated that this method was confined mainly to thin coals, and he thought 4 to 5 feet the most favourable thickness, an opinion echoed in his section on mining in the New Statistical Account for Alloa⁵⁸. He does qualify his view, however, by saying that a seam of any thickness might be wrought longwall provided material could be found to fill up the waste, since it was this lack of rubbish which limited longwall to thinner seams. It may be that his views were developed partly from his experience of Balbirnie in 1814, where the Two foot seam was wrought by longwall 'on the Shropshire style', in which the roads had to be kept high enough for horses by cutting away the pavement and where 18 inches of roof stone had to be taken down along with the coal. This roof stone provided precisely the rubbish which he found missing in thicker seams and was used for banking up the wastes as well as securing the horse roads. The thinness of the seam, together with the high cost of horses, propwood and labour, meant that it would scarcely have been economic were it not for the good prices obtained for the coal. This would appear to confirm Duckham's view that longwall working 'brought thinner seams within the realm of

practical mining,⁵⁹, though in this case only just.

Later in the nineteenth century, longwall was adopted in seams of various thicknesses. For example, the Wemyss parrot seam, ranging in thickness from 12 inches to nearly 4 feet, was wrought longwall in 1845, while in the same year the Wellwood 5 foot seam was also so wrought. 1869 saw a number of Fordell seams working longwall, including the 4-foot Mynheer seam and the 6 foot 3 inches Blalowan, though the remark that this last seam, thickest in the colliery, was wrought 'formerly stoop and room, now longwall' implies that it may have been the latest to go over to the new mode⁶⁰.

By the end of the nineteenth century, longwall working was employed in seams of any thickness. In 1900, for example, all the seams at Lumphinnans No 1 pit were working longwall, including the Lochgelly Splint and Parrot seam which was 11 feet thick. A 1909 description of the Wemyss field is even more emphatic:

"Even the thickest seams are now worked by the longwall method, the Dysart-Main seam, at one place 25 feet thick, in from two to four horizontal slices or lifts; and the Chemiss seam, 11 feet thick, in two lifts....."⁶¹

Clearly, then, the advantages of longwall working had found application in the thickest seams of the Fife coalfield. The period over which this adoption had taken place extended over the hundred years from about 1770, with the period of fastest expansion in the mid nineteenth century. It is important to realise that the innovation of longwall working meant a significant change in working practices, so that while variants of stoop and room, even panel working, may be regarded as evolutionary, longwall was more of a radical change. Perhaps in this fact we have an explanation for its comparatively slow rate of development in Fife, in that its undoubted

advantages carried with them the need to adjust to an entirely new system of underground operations. Consequently, despite being introduced to Fife in 1771, it was not until about 1860 that the system became widespread. This process is illustrated in figure 6.6, which shows a sample of pits operating longwall workings at different dates, and also in figure 6.7, which gives the geographical distribution of that data. There are three possible sources of bias in this information.

First, the data was gathered from a variety of colliery reports and other sources. It follows that where a particular group of documents are especially comprehensive, or have simply survived complete (such as the Bald reports of the early 1800s, or the Geddes series of mid nineteenth century) then there may appear to be a sudden increase in longwall working which actually results from an increase in reports of longwall working. On the other hand, there is no reason to suppose that those collieries in our sample are atypical except in so far as the very fact of reports being made indicates a prudent attitude on the part of the owners.

Second, most of the entries in figure 6.6 represent a 'pit'. Original sources, however, sometimes refer to a 'colliery', which may include a number of pits. In this event, only one entry was made in the diagram.

Third, some references to longwall were simply recommendations by the reporter. We do not always know when, or even whether, such recommendations were put into effect.

Bearing these qualifications in mind, it is felt that the 41 references in the figure provide a reasonably accurate reflection of the progression of longwall working in Fife. The details are as follows:

Longwall was introduced to Scotland in 1760 by the Carron Company's importation of miners from the Shropshire coalfield. It appeared in Fife at Pitfirrane in 1771, where the Cadells were involved in a tack of the colliery. It was claimed at that time, perhaps optimistically, that the method was 'pretty generally adopted',⁶². In 1793, Lord Dundonald suggested longwall as one alternative to stoop and room working, the other being 'boardways fashion as at Newcastle',⁶³.

After 1800, longwall appeared in the Two foot seam at Balbirnie in 1814, but as we have already noted, the reference to 'Long Walls' in the Main coal of that colliery was to a form of room and rance working. The rate of innovation speeded up in mid century but at first longwall may have been seen as a desirable alternative to stoop and room rather than as a total and inevitable replacement. This is illustrated by a lease of Inzievar colliery in 1837, where the method of working was stipulated as longwall if possible, but otherwise stoop and room⁶⁴. About this time a number of recommendations appear in which longwall is identified as being more beneficial than stoop and room. It was, for example, 'most advantageous for the proprietor' at Baldrige in 1840⁶⁵ and 4 years later was the 'new and most approved mode' at nearby Wellwood⁶⁶. In 1845 the longwall system in Wemyss Parrot seam was 'the most satisfactory of all',⁶⁷ and an oversman's fortnightly report for that colliery in February, 1846 illustrates how, despite these claims for the efficacy of longwall, it had failed to achieve a wholesale displacement of stoop and room. The report refers to pillars in the Rough seam, implies stoop and room workings in the Barncraig coal, and mentions that longwall workings in Pirnie pit were being opened out as fast as possible⁶⁸.

By the 1860s the innovation process was considerably more

advanced than this and figure 6.6 suggests that the rate of progress began to slow down, the main thrust of innovation having passed. This view is confirmed by the fact that it appears to have been no longer necessary to state the usefulness of longwall, and references simply say that it was employed.

The innovation process was at least partially controlled by the conditions laid down in colliery leases, sometimes providing freedom for the tenant to introduce a new method, but more often being quite specific about how the coal should be worked.

An early example is an agreement of 1771 between John Beaumont and the Cadells which refers to their lease of Pitferrane and requires that the works shall be carried on 'upon the same plan as mentioned in the Articles of Copartnery for Grange Colliery'.⁶⁹ This is apparently a reference to longwall, and the innovation was carried on in a Pitferrane lease of 1815, where the longwall method was stipulated for the Splint seam⁷⁰.

On the other hand, stoop and room was specified in a Cuttlehill lease of 1798 and the tenant was obliged 'to leave sufficient and substantial pillars and stoops of coal for supporting the...roofs'.⁷¹ Other leases were more specific. For instance, Bald suggested in 1814 the propriety of having room and pillar sizes settled for future operations at Baldrige⁷². This was actually the case, but a report of 1818 shows that the stipulations had been ignored in working the coal⁷³.

Later in the century, the fact that several methods were in use is reflected in the conditions of lease for the period. A choice of longwall or stoop and room might be given, as at Inzievar in 1837⁷⁴, or Kilmux in 1874⁷⁵. At Methil, on the other hand, the 1856 lease specified longwall⁷⁶, as did the Cowdenbeath tack in 1865, though in

the latter there was a realistic amount of flexibility since 'all seams suitable for the longwall method shall be so worked'⁷⁷. An 1849 lease of Balgonie implies a stoop and room mode in that the sizes of rooms and pillars were to be given by the landlord's viewer⁷⁸ while the Foulford lease of 1872 required the panel system to be employed⁷⁹.

In general, it is difficult to say whether leases were an active agent of innovation or whether they simply reflected a process which would have gone on anyway. If leases did influence longwall innovation, did they advance or retard it? If we see the conditions of a lease as being an attempt to control a tenant and maintain the value of the property as long as possible, they would likely err on the side of caution and conservatism. Consequently, the conditions of lease are more likely to reflect technological change rather than to institute it, and this view finds some confirmation in a look at 14 leases spread over the hundred years of longwall innovation. Six specify longwall, 6 stoop and room, 1 either longwall or stoop and room and 1 lease specifies panel working. Most stoop and room come in the first half of the period, most longwall come in the second. Leases on the whole tended to reflect technological innovation rather than instigate it.

Figure 6.6 shows quite clearly that the main thrust of longwall innovation was over by about 1880, although longwall had not entirely displaced stoop and room, and figure 6.7 suggests that much of the longwall activity had gone on in the West. This was the area of the coalfield developing most forcibly in mid century, and we might expect this to be associated with a willingness to innovate. However, in some places the retention of stoop and room was not only feasible but necessary well into the late nineteenth century, helped by particular

geological conditions or the need to prevent the immediate subsidence which followed longwall operations.

For example, at Cowdenbeath in 1870/71 various comments by Geddes make it clear that the Five Foot seam was too soft for longwall extraction, producing the lowest yield he had ever known in a longwall working. Consequently, stoop and room was employed⁸⁰. More than 20 years later, in 1894, it was the nature of the roof rather than the coal which prompted the working of a seam at Kinnead by stoop and room⁸¹.

Regarding the prevention of crushes, Lassodie in 1870 provides an instance of the use of stoop and room in a seam otherwise wrought longwall. It was felt that longwall working of the Splint seam would cause a crush of the pillars in the Five Foot seam above, so the Five Foot workings were to be stopped until the Splint face had gone beyond them and, significantly,

"the workings in the Splint underneath them should be put upon stoop and room till they are clear of doing damage"⁸²

Despite problems such as these, the complete removal of the coal in one working was an advantage with which stoop and room could not compete, and more than made up for the extra expense of propwood and road maintenance which longwall working entailed⁸³. This complete removal produced subsidence at the surface, however, and special areas or pillars of coal were left for the protection of both workings and surface features. This was how the Fife miners coped with Galloway's claim that where surface damage had to be avoided or where workings extended under rivers 'the longwall system of working is under such conditions inadvisable'⁸⁴. Some examples will serve to illustrate the point.

Bald, speaking generally in 1830, referred to the formation of

very large pit-bottom pillars and to the leaving of long pillars or 'chains of wall' along the dip-head levels⁸⁵. These are illustrated in figure 6.5.

In a specific instance from the same writer, we find that Balbirnie workings in 1814 were given a measure of security by leaving at least 6 fathoms of coal next to the day-level, essential if drainage was to be maintained, while shafts to the Main coal were protected by large square pillars of coal left amidst the longwall workings of the Two foot seam⁸⁶. Similar provision was made for shafts in the Methil lease of 1856 which also provided that no workings were to be carried within 20 yards of the River Leven or any farm steading⁸⁷, but it was a railway tunnel which needed protection at Lumphinnans in the mid 1860s. A special pillar was left and became the subject of a successful compensation claim against the railway company.⁸⁸

The general picture of subsidence in longwall working is aptly illustrated in the case of the Lochgelly Splint coal in Carden colliery which was described by John Williamson in May, 1859⁸⁹. He points out that the total height of excavation was 6 feet, 18 inches of that being material (mainly fireclay) available for stowing in the waste. This left a height of 4 feet 6 inches which in his opinion would produce a surface subsidence of about 3 feet. We may note that this figure accords with that given for Dunfermline by Chalmers about the same time, where an excavation about 4 feet high was reduced to some 15 inches in about 6 months⁹⁰. Williamson pointed out that longwall working, besides producing a direct vertical subsidence, also lowered the surface for some distance beyond the perpendicular by what he termed the 'draw'. This draw preceded workings as they gradually advanced and he claimed that this allowed time, in the case

of a railway line, to 'bank up the rails from day to day'. He thought this was more economical than causing an entire pillar to be left under the line. Despite this, the Fife practice was normally to leave a pillar, even if it had to be a large one to eliminate damage from the draw.

By comparison, no draw or subsidence took place in stoop and room working, but here the ground was liable to sudden collapse, even many years later. Williamson concludes:

"the working by longwall is in this respect the most desirable way, as the effects of it are gradual and unless under very peculiar circumstances, at rest for ever."⁹¹

While longwall innovation improved the degree of subsidence control, it also provided mining engineers with the opportunity to develop other mining techniques. These included the possibility of a greater division of labour, the introduction of machine mining, better ventilation and, as a result of these things, higher output and productivity.

Division of labour seems to be generally regarded as a significant feature of longwall mining but evidence of this in the Fife coalfield is difficult to find. The contemporary account we have from Bald in 1830 is among the most authoritative evidence, but of course does not refer to any specific locality. However, Bald was already well acquainted with the Fife field, so it is reasonable to assume that his remarks would apply to longwall workings there. He described longwall workers as being in 3 groups: Holers, Getters and Buttymen. The Holers undercut the coal face, the Getters drove down the coal with wedges and sometimes gunpowder, while the Buttymen broke up and cleared the coal then advanced the timber props and extended the stone supports⁹². However, the three groups were not

so clearly differentiated as to merit separate listing in the 1842 report of the Children's Employment Commission, where 7 types of workmen are noted⁹³. Presumably, Holers, Getters and Buttymen are all subsumed under 'Hewers'. In the Elgin colliery of 1856, the Special Rules list 8 types of workmen, together with their duties, but again we find that an undifferentiated 'colliers' category seems to cover the range of coalface activity⁹⁴. The 'rules' for this group are mainly concerned with the selection and use of wooden props. There is a reference to 'Brushers or Reddsmen, or colliers acting as such' who were responsible for maintaining roads. This phrase may imply a certain flexibility in the division of labour which could make a man a Holer, Getter or Buttyman as the situation required. Census enumeration books from mid nineteenth-century Fife categorise all these workers as 'coalminer' or 'collier' and while this may not be unexpected, it serves as a further example of how a division of labour which may have been real enough underground, was not reflected in any rigid classification of face workers in contemporary documents.

Longwall working had rather more significance for machine mining, and was important in two respects. First, longwall brought thinner seams into economic working and it was generally agreed that machine mining was more economical in such seams⁹⁵. Second, the establishment of a long coal face was an essential prerequisite for the successful application of mechanical cutters and conveyors. Longwall was in this respect an 'enabling' factor which allowed machine mining to be introduced as soon as suitable designs and power sources had been developed.

The coal-getting operation consisted of undercutting the seam at or about floor level so that the coal above the groove would drop

by itself or could be driven down by wedges or explosive. Under-cutting by hand, possibly to a depth of 3 feet (0.91 m), required a wedge-shaped opening to give the miner clearance to wield his pick and this involved considerable breakage of coal. Early attempts to mechanise this process date from the 1760s and tried to emulate the percussive action of the miner's pick. Despite appearing in a number of guises, these machines never achieved wide acceptance and Cunningham informs us that by 1895 there was not a single 'iron man' in operation in Fife⁹⁶.

Various patents of the mid nineteenth century reflect the attempt to apply rotary motion to coal-cutting, and some success was achieved with the disc machine which operated in principle not unlike a circular saw (see figure 6.8). Harrison's design of 1863 can be regarded as the first practical coal-cutter. About the same time, the two other main types - the chain-cutter and bar-cutter - were being developed. The former consisted of an arm carrying an endless chain on which were mounted the cutters, while the latter had a projecting bar armed with cutters throughout its length and which rotated at high speed (see figure 6.8).

As early as 1866, Landale, manager at Lochgelly, was investigating the details of a rotary coal cutter with a Tyneside firm⁹⁷, and by 1872 we know that Little Raith colliery had been using a coal cutter, for an inventory of that year lists 'coal cutting machine rails' in the Lady pit⁹⁸. Soon afterwards, a cutter of what was described as 'the old-fashioned disc type' was installed in the Jersey seam of the Wee pit, Lindsay colliery⁹⁹, implying that perhaps the disc machine had by now been superseded. This was not the case, however, and even as late as 1912, disc machines were still the most numerous in British collieries, though by this stage many different

designs had been developed. In August, 1884, for example, Charles Carlow of the Fife Coal Company heard of a new machine and bought one for trial at the Kelty pits of the company¹⁰⁰. By 1911, this one company had no fewer than 116 coal cutting machines in operation in Fife and in 1913, 35 out of 60 working mines in Fife had coal cutters at work¹⁰¹. Their distribution is shown in figure 6.9 and exhibits a marked concentration in Central Fife, where lay most of the industry's development at that time. There is a lesser concentration in the Eastern part of the coalfield. Considering the tripartite geological division of the Fife field into West, Central and East sections, it was thought possible that the distribution of coal-cutters in 1913 was related to the geological conditions in different parts of the field. Cutters could be used in thin seams where hand hewing was particularly difficult or uneconomic, but tended to be less advantageous in faulted areas or steeply inclined seams. However, on investigation it was found impossible to adequately explain the geographic distribution of coal cutters in terms of geology. The greater incidence of faulting and volcanic intrusions in Central Fife would, if anything, work against the innovation of machine mining in that area, and an attempt to relate coal cutters with the working of thin seams proved unsuccessful. Nevertheless, Crowe does suggest that the Coal Measure areas have thicker individual seams, so this point may have some relevance for the lower concentration of machine mining in the Eastern part of the coalfield¹⁰². On the whole, though, while individual examples of geological influence may be identified, no general relationship is evident. An individual case of the sort of relationship which can occur is the use of a coal-cutter in the Mynheer seam at Dundonald Colliery about 1905. Here, we have a seam of strong, hard

coal 33-36 inches (83.8 - 91.4 cm) thick. Because of its hardness and thinness, a good miner might produce $1\frac{1}{4}$ tons (1.27 tonnes) during a shift, which was scarcely an economic output when coal prices were normal. Consequently, J M Thomson, General Manager at Dundonald, introduced one of Gillot and Copley's coal-cutters, powered by compressed air. In three months, output rose from 50 tons (50.8 tonnes) per day to 250 tons (304.8 tonnes), and within a short time three of these disc cutters were at work¹⁰³.

If we cannot entirely explain the distribution of coal-cutters by geology, it may be that at least part of the answer lies in the role of the coal companies. For instance, while the Wemyss Coal Company employed cutters in only 3 of its 8 working pits in 1913, the Lochgelly Iron and Coal Company had machines at work in all of the 8 which it controlled, and the Fife Coal Company had cutters in 18 of its 23 pits. Since both the Fife and Lochgelly companies operated mainly in Central Fife, enthusiasm for machine mining within those companies could have been instrumental in producing the distribution shown in the figure. In this respect we might direct our attention to the role of individuals in innovation, with Landale's early (1866) work at Lochgelly, Carlow's willingness to try out a new machine in 1884, and Thomson's introduction of cutters at Dundonald some 20 years later. It seems that the innovation of coal-cutting machines in Fife represents an entrepreneurial response to a problem with an economic as well as a physical basis. It was no less successful for all that. By 1913, although England and Wales had only 6.2% of its output cut by machine, Scotland had 21.7% and at Lochgelly the figure was about 28%¹⁰⁴. Without the prior adoption of the Longwall system, such a speedy and effective take-up of cutting machines would have been

impossible.

The spread of longwall also signalled an escape from the ventilation problems inherent in stoop and room working, particularly in that it greatly simplified the path which the air took underground, but also in the elimination of old waste spaces where dangerous gases might collect. At Dunfermline in 1844, for example, we are told that there was greater security against fire-damp or choke-damp because of the lack of 'vacant spaces'. Furthermore, 'whatever there may be of this gas is dispelled by a current of good air..... along the wall faces before the workers',¹⁰⁵.

The benefits of longwall working itself, then, were first, it allowed all the coal to be removed. Second, it made thinner seams economical and third, it meant that subsidence of superincumbent strata could be at least predicted and to a certain extent controlled. Less direct benefits included the (flexible) division of labour, the eventual introduction of machine mining and easier ventilation.

All this meant that productivity and output were significantly improved, echoing in Fife Langton's view of the Lancashire industry, that longwall development was a major factor in accounting for observed improvements in productivity¹⁰⁶.

Duckham's opinion is that although longwall brought greater productivity, it created problems of subsidence, of costly maintenance of long roads, and of dangers from ill-ventilated wastes. This is not a conclusion the Fife evidence would support. However, longwall innovation cannot be viewed in isolation. It must be seen within its context of changing mining technology, in which it played such an important part that without it, other innovations would have been either limited in feasibility or altogether impossible. In Fife, longwall innovation was precisely as Ashton and Sykes described it.

TABLE 6.1 - Dimensions of stoop and room workings

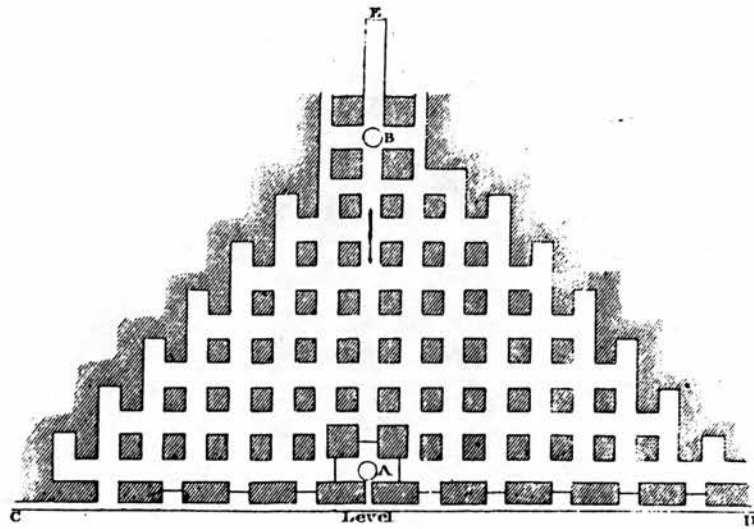
Date	Location	Pillar shape	Pillar size(ft)	Pillar ₂ area (yd ²)	Width of rooms(ft)	Remarks
cl676	Wemyss	rec	30 x 18	60	12	
1738	Strathore	squ	12 x 12	16		
cl739	Strathore		8 x ?		8	
1739	Cluny	rec	8 x 9	8	10 - 12	
1739	Coalden				10 - 12	
1752	Cadham		18 x ?		6	
cl771	Pitferrane	rec	(6-30)x(4½-6½)			Pillar area not reliably calculable. Rooms 'larger than the norm'.
1787	Balgonie	rec	12 x 24	32	12	
1810	Townhill	squ	12 x 12	16	12	Pillars 12 x 15 'where the cover is heavy'.
1814	Balbirnie	squ	9 x 9	9	9	
1817	Dysart	dia	37 x 37	152	16	
1817	Baldrige	rec	12 x 9	12	13 - 14	
1818	Baldrige	rec	12 x 18	24	12	
1819	Balgonie	rec	10 x 16	18	12	
1828	Dysart	squ	37 x 37	152	17	'rooms not more than 17ft'
1840	Thornton		15 x ?		13	
1840	Baldrige	squ	15 x 15	25	12	
1845	Wemyss	squ	15 x 15	25	14	
1845	Wemyss	squ	18 x 18	36	14	
1845	Wemyss	rec	12 x 15	20	15	
1845	Wemyss	rec	18 x 50	100	14	proposed

TABLE 6.1 - Continued

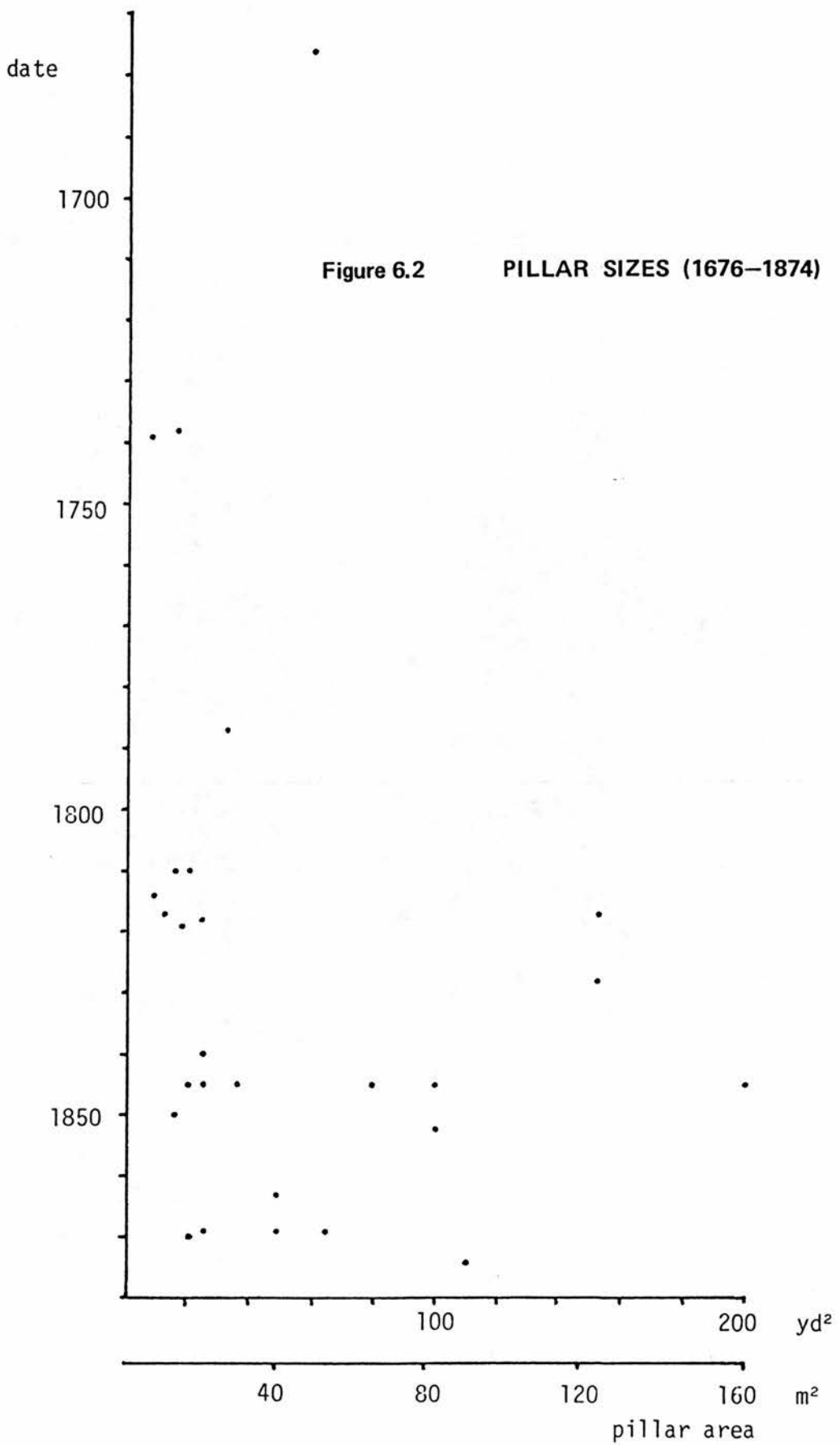
Date	Location	Pillar shape	Pillar size(ft)	Pillar ₂ area (yd ²)	Width of rooms(ft)	Remarks
1845	Wemyss	rec	18 x 40	80	20	proposed
1845	Wemyss	rec	36 x 50	200	14	proposed
c1850	Methil	squ	12 x 12	16	12	
1852	Cuttlehill	squ	30 x 30	100	12	pillars 'larger than usual'
1863	S Comrie	squ	21 x 21	49	13	
1869	Fordell	squ	15 x 15	25	13	Mynheer seam
1869	Fordell	squ	21 x 21	49	13 - 14	Splint seam
1869	Fordell	squ	24 x 24	64	14	Blalowan seam
1870	Lassodie	rec	15 x 12	20	14	
1874	Kilmux	rec	15 x 66	110	30	actually 'Room & Rance' system?

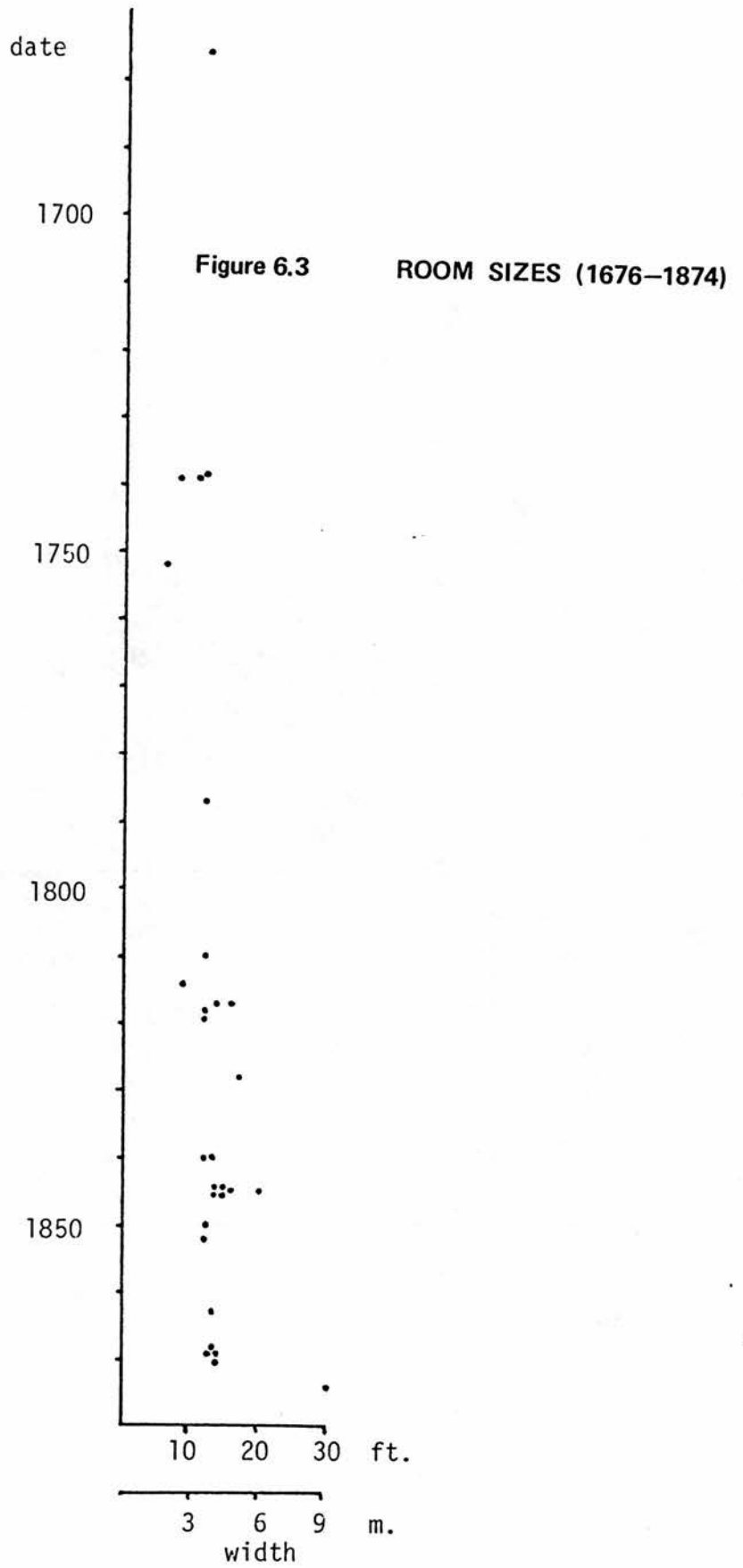
Pillar shapes : rec - rectangular
squ - square
dia - diamond

Figure 6.1 STOOP AND ROOM WORKING

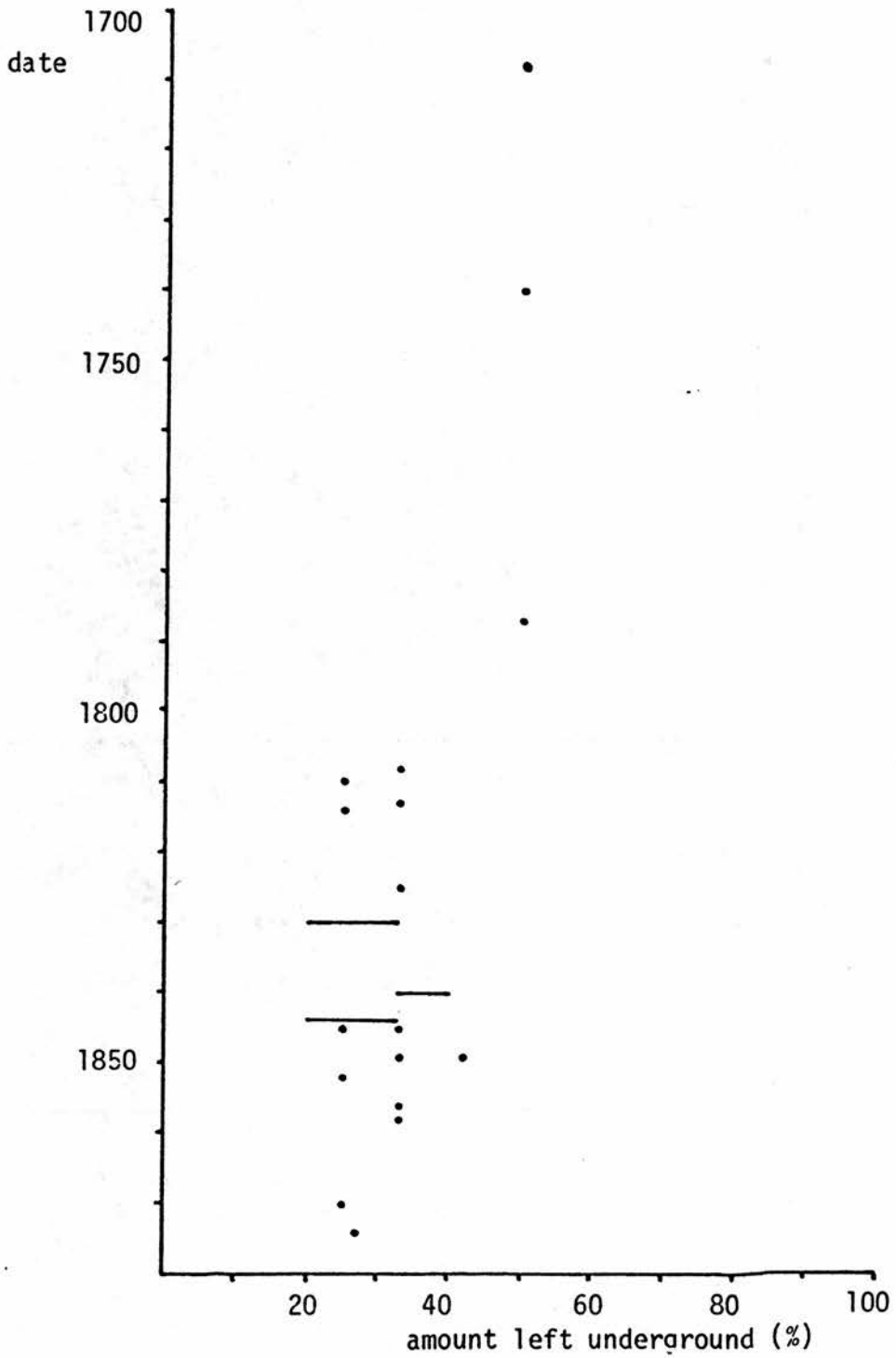


- A - engine pit
- B - bye pit
- CD - diphead levels
- E - crop mine



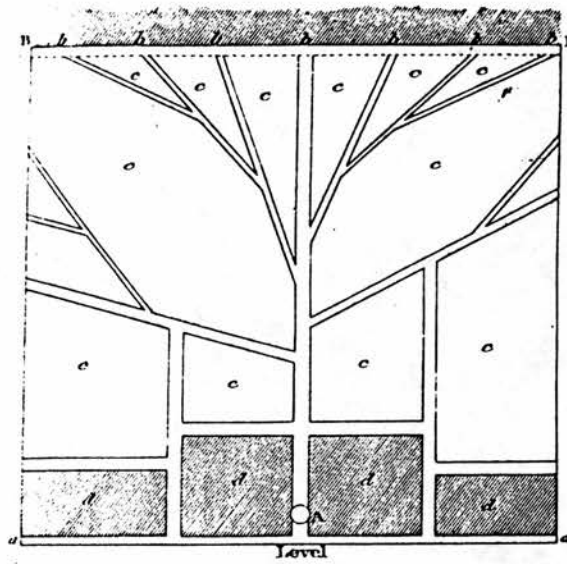


PROPORTION OF COAL LEFT AS PILLARS (1708-1874)



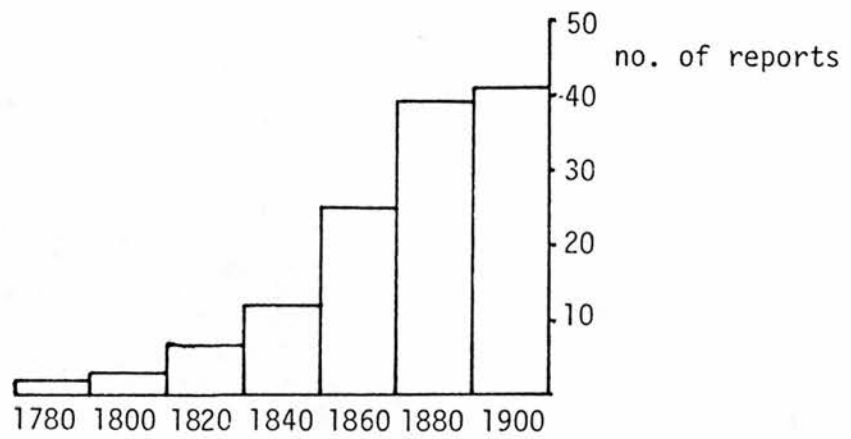
where a range of values is given, a line is used in this diagram.

Figure 6.5 LONGWALL WORKING



- A - engine pit
- aa - diphead levels
- BB - wall face
- b - roads
- c - gobbs or waste
- d - pillars

Figure 6.6 LONGWALL INNOVATION



Each column represents the number of reports of longwall working in Fife which had appeared by the date given. Reports total 41.

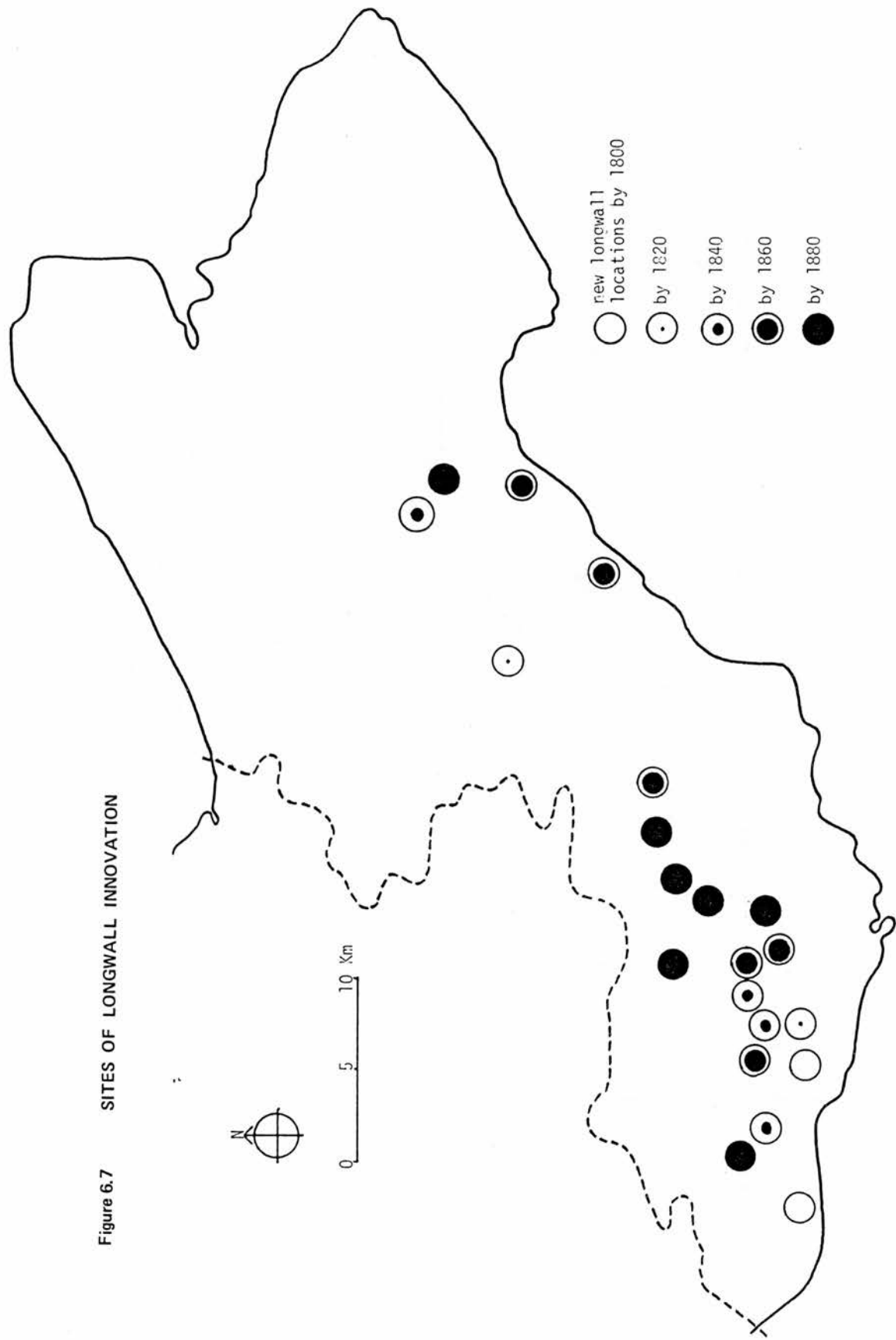
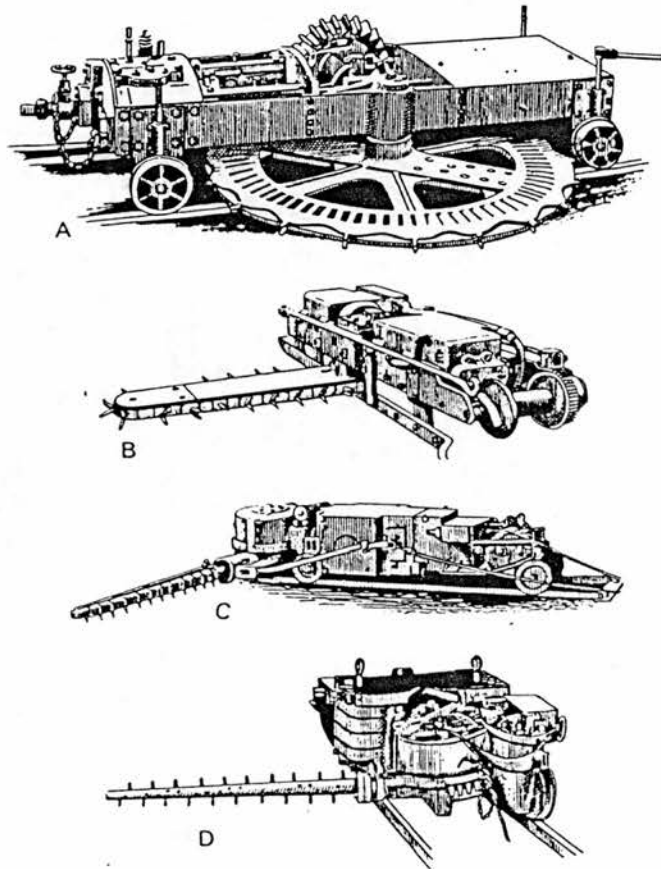


Figure 6.7 SITES OF LONGWALL INNOVATION

Figure 6.8 COAL CUTTERS



Three types of coal-cutter: A - disk
B - chain
C and D - bar

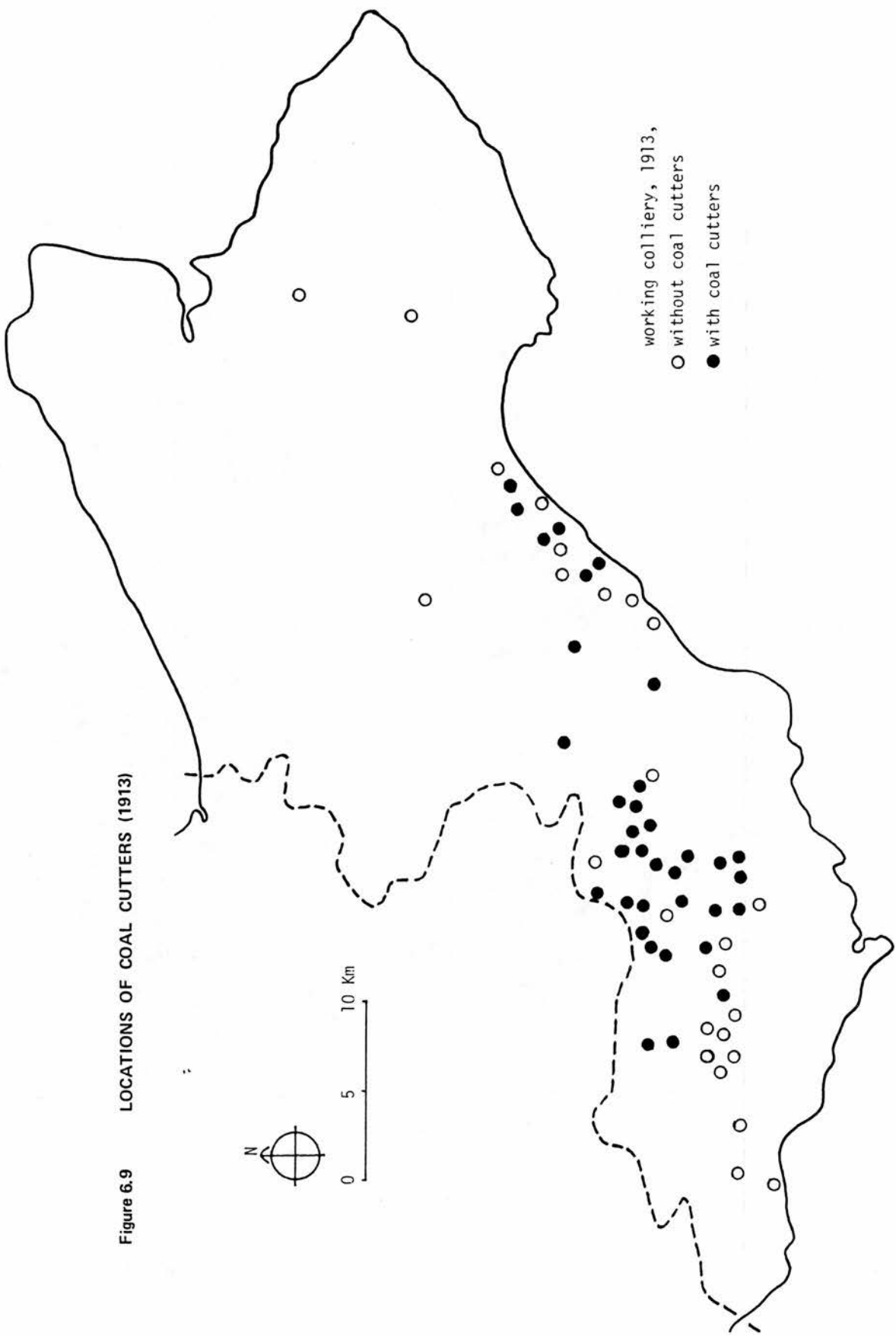


Figure 6.9 LOCATIONS OF COAL CUTTERS (1913)

CHAPTER 7 - UNDERGROUND HAULAGE AND WINDING

Improvements in haulage and winding have long been the targets of technological innovation, for it was in the transit from face to pithead that there lay a potential major bottleneck in the coal production process. The progression from human muscle-power through horses to steam engines and, finally, electricity in the early twentieth century covers the entire period with which we are now concerned. By taking each power source in turn, we can most logically examine the process by which haulage and winding were improved in the 164 years after 1750.

The most primitive form of underground haulage was the use of manual labour, most notoriously in the employment of female 'bearers'. Normally working for a collier husband or father, these women and girls would carry back-breaking loads through the mine and sometimes up a 'stair' to the surface. (See figure 7.1). In a telling description of the method, the Report of the Children's Employment Commission refers to an 11-year old girl:

"She has first to descend a nine-ladder pit to the first rest, even to which a shaft is sunk, to draw up the baskets or tubs of coal filled by the bearers: she then takes her creel (a basket formed to the back, not unlike a cockle-shell flattened towards the neck, so as to allow lumps of coal to rest on the back of the neck and shoulders), and pursues her journey to the wall-face, or as it is called here, the room of work. She then lays down her basket, into which the coal is rolled, and it is frequently more than one man can do to lift the burden on her back. The tugs or straps are placed over the forehead, and the body bent in a semicircular form, in order to stiffen the arch. Large lumps of coal are then placed on the neck, and she then commences her journey.....the height ascended, and the distance along the roads added together, exceed the height of St Paul's Cathedral.....However incredible it may be, yet I have taken the evidence of fathers who have ruptured themselves, from straining to lift coal on their children's backs."

Dundonald had proposed the abolition of this haulage method in

1793², and in 1808 Bald was also critical of a system which he held responsible for the degraded lot of many collier families. Bearing was "severe, slavish, and oppressive in the highest degree"³.

The miseries of bearing are already well documented, so we may more usefully address ourselves here to an examination of its effectiveness as a haulage method. First, we will consider the loads carried. Second, we will look at the numbers employed, particularly in relation to the number of hewers at work, and third, an examination will be made of the process by which bearing was superseded by putting and more sophisticated haulage and winding technology.

The amount of coal which a bearer could carry varied with her age and strength, but generally seems to have been between one and two hundredweight (51-102 Kg). Bald put it at $1\frac{1}{2}$ cwt (76 Kg)⁴, but the Children's Employment Commission gives a range of $\frac{3}{4}$ to 3 cwt, the higher figure probably appearing in 'trials of strength' rather than being a normal load⁵. Young children carried lighter loads. For instance, a 'perfectly beautiful' child of 6 bore 56 lb (25 Kg) while a girl of 11 carried between 1 and $1\frac{1}{2}$ cwt (51-76 Kg). A 16-year-old was capable of bearing 2 cwt (102 Kg), but thought that $2\frac{1}{2}$ -3 cwt (127-153 Kg) was 'overstraining'⁶.

By employing a large number of bearers, a colliery could produce considerable quantities of coal for no capital investment whatever in haulage. Bearers were paid by the hewers for whom they worked and in a system where colliers could get haulage performed very cheaply by their families, there was little incentive for a coalmaster to incur capital and maintenance costs by installing underground railways, buying horses, or erecting machinery. We are told that when the Earl of Mar ended bearing, some 50,000 tons of coal per annum

were being raised from his Alloa pits solely by female bearers⁷. At an average of something like 9 tons per week each⁸, this output would have required the employment of about 107 bearers, a not unreasonable figure.

In Dunfermline parish, Fife, 140 bearers helped to provide an annual output of 90,000 tons (91,440 tonnes), which works out at just over 12 tons (12.1 tonnes) per bearer per week. However, with '200 horses employed above and below the surface', a considerable part of the output would have been hauled by methods other than bearing, so the weekly output of a bearer must have been substantially less than 12 tons (12.1 tonnes)⁹. On the other hand, Thomson estimates an average of only 2.4 tons (2.4 tonnes) per week for the Rothes pits about 1740, not including small coals¹⁰, but it is felt that an average of about 7.5 tons (7.6 tonnes) per week is a more likely figure over Fife as a whole, despite being derived partly from Lothians evidence to the Children's Employment Commission of 1842. Certainly, it accords more closely with the Alloa figure and would also approximate to our Dunfermline estimate.

The distance over which this load was carried varied with the nature of the workings. The Lothian evidence of 1842 suggests a maximum underground distance of 250 fathoms (457 m). The length would be much shorter than this, though, if the bearer was also expected to climb a stair pit to the surface. As a result, bearing pits were inevitably huddled together, and Goodwin has identified early pits in Fife as being closely spaced for this reason¹¹. Similarly, bearing pits were shallow. The writer of the Alloa OSA suggested an 18-fathom (33 m) maximum¹², and those at Rothes were well within this limit, being at most 16 fathoms (29 m)¹³. The stair pit at Balbirnie in 1814 was also less than 18 fathoms deep but at that date haulage

was by horses and it seems that the stair was by then for access only. This was also the case at Baldrige stair pit. When a road was blocked by subsidence, it was found 'very inconvenient for the work-people to descend and ascend by the gin'¹⁴. This stair pit is unlikely to have been very deep, situated as it was in a direction 'a-cropping', but at nearby Townhill, a stair pit had been sunk as far as the Splint coal. By 1818 this colliery already had a tramming system of haulage, so the stair pit of that date would have been used not for bearing but for access¹⁵. Butt has pointed out that even in 1842, East of Scotland pits were still commonly descended by turnpike stairs or by a single ladder down a shaft¹⁶. Many of the shallow stair pits in Fife would have been proper bearing pits, at least originally, the deeper stair pits being constructed for access rather than for the raising of coal. Unfortunately, we do not have enough information to classify them by depth.

Bearing, whether up a stair pit to the pithead, or simply along roads to the pit-bottom, could not cope with the deeper mining and expanding scale of production taking place after about 1800. As a haulage method, it was essentially a small-scale technique. Despite this, the Eighteenth century must have seen the employment of large numbers of bearers in Fife. By extrapolating some of the data given in the OSA it is possible to reach an estimate of the number of bearers working in Fife in the closing years of the Eighteenth century, and the figure is about 440. By this time, however, a considerable reduction had been made in the bearer population, a development which may be illustrated by looking at 3 examples of the hewer/bearer ratio.

In 1738, Strathore pits had 14 hewers to 15 bearers, a ratio of 1/1.07¹⁷. (This may help to explain Thomson's low figure of 2.4 tons (2.4 tonnes) carried per week by each bearer. He calculated from a

hewer/bearer ratio of 1/2. A ratio of about 1/1 would give a more realistic-seeming 5 tons (5 tonnes) carried per week). By 1771, Pitfirrane Colliery had 20 hewers to 24 bearers, a ratio of about 1/1.2¹⁸, but by the time of the Old Statistical Account, Dunfermline Parish had 180 hewers to 140 bearers, a ratio of 1/0.78¹⁹. This relative decline of bearer numbers continued so that in the second two decades of the Nineteenth century, Bald's 40 reports on 24 Fife collieries could remark on no instance of the method still in use. Nevertheless, the evidence to the 1842 Children's Employment Commission shows that bearing had been in use at Wemyss until about 1840, partly because it was still cheaper than using small hutches²⁰. Also, Chalmers indicates that although bearing was no longer to be found in Dunfermline parish by 1842, a few had been so employed at Townhill, possibly as late as 1838²¹. It is known that 'tramming' was operating at Townhill by 1810, so bearing to the pit-bottom must have been employed alongside the more sophisticated technique. In general, the Fife case tends to confirm the view of Ashton and Sykes, that at the beginning of the Eighteenth century, far more labour was employed in moving the coal than in hewing it, but within a century, hewers almost always outnumbered the drawers²². This change was at least partly due to the more effective use of manual labour in the process of 'putting' or 'drawing'. (See figures 7.2 and 7.3).

Barrowman defines a 'drawer' as 'A man or boy who takes the minerals from the working face to the shaft, or terminus of the horse or haulage road'²³. A 'putter' was simply an assistant for difficult parts of the route and a 'trammer' is defined simply as 'a drawer'. The literature uses the terms 'putter' and 'drawer' interchangeably, but 'trammer' properly refers to a person working with wheeled containers on wood or iron rails. As the terms for the workers varied,

so did the terms for the coal containers which they manhandled through the mines. The earliest was probably the 'slype', a sled on which the coal was placed for dragging to the pit-bottom. The 'hutch' was a considerable improvement, being an oblong box with four wheels, initially drawn along the pavement but later set on wood, then iron, rails. Slypes of 2-3 cwt (102-153 Kg) being drawn along the pavement by manual labour was criticised by Bald as being:

"...among the worst plans; for in no instance can the strength of a man be applied with less effect than in this way."²⁴

In Fife, the substitution of putting for bearing seems to have taken place over the 70 years up to about 1840. The employment of bearers at Pitfirrane and Balmule in 1771²⁵ and at Lochgelly in 1777²⁶ gave way to a much more varied system of haulage by the time of the Old Statistical Account. About 20 years later, Bald's reports paint a picture in which tramming and horse-haulage feature strongly, and by the time of the 1842 Commission, bearing had disappeared from Fife pits, the manual haulage to pit-bottom or horse-road being carried out by large numbers of putters working with hutches.

The improvement in output which accompanied this change may be assessed by looking at the amount of coal a putter could shift in comparison with a bearer's output. Even using the evidence to the Children's Employment Commission, no estimate of a putter's output can be very reliable. Hutches varied in capacity from $1\frac{1}{2}$ to 10 cwt (76-510 Kg) and the number of trips ('races') would vary with the method of drawing, the nature of the roads and, of course, the strength of the putter. Assuming a mean load of 4 cwt (204 Kg) - derived from 12 examples - and an average number of trips of 25 per putter²⁷, we have 25 tons (25.4 tonnes) moved per week, compared with $7\frac{1}{2}$ tons (7.62 tonnes) for a bearer. Allied with the use of horses on main

roads and winding by machinery, this meant an increase in coal production despite the comparative decline in the number of haulage workers which we have already noted.

Figure 7.4 shows the estimated numbers engaged in underground haulage at 29 Fife collieries in 1842. The estimated total of 718 was derived as follows: First, it was assumed that all underground female employees were engaged in haulage. Since a number of female children were employed as trappers or pumpers, this will slightly overestimate the haulage numbers. The female total was then increased by a proportion to take account of the likely number of males employed in haulage. While this is not entirely satisfactory as a procedure, it is felt that the resulting figure, at 28% of the underground workforce, is of the correct order.

Two features of figure 7.4 require comment. First, the numbers are dominated by 5 large collieries: Elgin, Wellwood, Halbeath, Fordel and Wemyss. The simple explanation for this is that being large enterprises, their output of coal required large numbers of people to move it. By 1842 all five employed steam winders and underground rail-roads, which meant that the main haulageways had a high capacity. To keep this capacity occupied, and so justify the capital investment, a large number of putters had to be employed in moving coal from the faces to the main roads. In this respect, it may be said that technological innovation actually increased the use of human muscle-power underground, at least for the time it took for haulage innovations to reach as far as the coal face.

Second, figure 7.4 shows 11 collieries at which no women were employed underground. All 12 employed only small numbers of people in haulage work and it may be that, being small collieries, their limited outputs could be hauled by the available male labour. In

other words, women were not needed because there was no effective shortage of local male labour. If this is true, we could expect to see evidence of some geographical concentration among these 11 collieries, and to some extent we do. The figure shows them predominantly in East Fife, a location which might be partly explained by an implication in the Drumcarro evidence of 1842:

"No females have ever wrought in this part of Fife, and many of our present colliers were labourers in the fields; they are generally good workmen, although they are called grass-colliers."²⁸

In the East, the collier community was less segregated from other workers and formed a small proportion of the total population, so the introverted collier-community practice of females performing underground haulage was never adopted. Indeed, at Largoward hewers did their own putting to the pit-bottom. This must have been an arduous task on the unrailed roads, but it explains the appearance of Largoward on figure 7.4 as having no persons employed in underground haulage.

Before leaving manual haulage, we may note the technique which was to develop into the horse-gin, and which had been long employed as an alternative to bearing pits - the hand windlass. Clerk noted in 1740 that it was sometimes employed for raising coals where the depth was less than 8 or 10 fathoms (14.6 or 18.3 m)²⁹. Nearly 100 years later, Bald found it still used in shallow pits of low output³⁰, so it was probably quite common in Fife from the early 18th century. Thomson remarks on its use at Cluny in 1751³¹. Sometime after 1777 it was introduced at Lochgelly where it eased the work of bearing and helped to raise output by 50%³², and even as late as 1842, evidence from Dundonald colliery points to the use of women's labour in winding coals up incline-wheels³³.

By this time, however, the horse had long replaced the female

as the principal beast of burden in mine haulage, so that the Act of 1842, in preventing the underground employment of women and children, had simply set the seal on a process of change already well advanced in Fife. Horse-power was an important and long-lasting innovation in both haulage and winding functions, and it is convenient to examine these roles separately.

The use of horses or ponies in Scottish underground haulage lasted from the mid 18th century until well beyond 1914, and although we have no firm date for the innovation of horse-haulage in Fife, the Old Statistical Account records that horses were working underground in Wemyss, Dysart and Dunfermline parishes. Certainly, in 1787 William Casson recommended horses for Balgonie³⁴, so it seems likely that the late 18th century saw the innovation in full swing. We know Balgonie did, in fact, employ horses underground by 1802, as did Dysart (1794), Halbeath (1812), Balbirnie (before 1814), and Fordel (1817)³⁵. Unfortunately, the information we have about numbers of animals is too fragmented for useful generalisation. For example, although the OSA tells us that Dunfermline parish employed 200 horses in coal mining, we do not know how many of these were underground³⁶. A more specific figure given for about 1842 states that of only 68 horses, 18 were underground³⁷, while by 1857 about half of Dunfermline's 98 animals were employed below the surface³⁸.

A possible interpretation of these figures is that the majority of the OSA number was working on the surface, probably in winding, while by 1842 many had been displaced by steam. At the same time, there was a period early in the 19th century when horse-power was relatively expensive, and underground animals must also have diminished in number. In this respect we may note Bald's comment at Balbirnie in 1814, where he proposed:

"in place of horses to substitute iron railways and trammers below ground, as the expence of horses is uncommonly great and every colliery is now giving up horses and resorting to the tramming system"³⁹

At Townhill in 1810 he thought the Tramming system then in operation was about 40% cheaper than the horse system found in many collieries⁴⁰, and elsewhere comments adversely on horse-drawn slypes at Fordel and Balgonie⁴¹. After 1842, the impetus provided by Lord Ashley's Act encouraged the use of more underground horses to replace the now proscribed female and child labour, and the growth in Dunfermline's underground numbers from 18 in 1842 to about 50 in 1857 reflects this change. The number of surface animals remained steady, their displacement by steam already substantially over by 1842.

Subsequently, horses were to remain a major source of power for haulage, working at first on main roads, but increasingly right up to the wallface. Of course, this meant wider and higher roads which were more expensive to drive and maintain, but the effort seems to have been worthwhile. For example, deep roads had had to be cut in the pavement at Balbirnie to let the horses draw coals from the face to pit-bottom⁴². The lowest horseway in Dysart in 1842 was 6 feet (1.83 m) high⁴³, and at Wellwood the main roads were 6 to 6½ feet (1.83-1.98 m), with wallface roads having a height of no less than 4 feet (1.22 m)⁴⁴.

The amount a horse could pull varied with the nature of the road and whether it was railed or not. Horse-drawn slypes often contained between 4 and 6 cwt (294-306 Kg) of coal, but were inefficient, since 'the strength of the horse is applied with the very worst effect'⁴⁵. It was only when horse-power was allied with wheeled hutches and railroads that amounts of more than a ton could be moved⁴⁶. The distances drawn were generally more than the bearing system could have coped with but not necessarily much greater

than some of the putting distances given in the Fife evidence to the 1842 Commission. For example, putters are known to have drawn coals all the way from coal face to pit-bottom at Townhill⁴⁷ and Capletrae⁴⁸, and the mean putting distance calculated from 7 examples given in evidence is some 350 yards (320 m). We have fewer examples of horse-drawn distances from which to calculate a mean, but it seems that the roads at Halbeath in 1812 may have been too long at 300-500 yards (274-457 m), being so situated 'that a horse could only bring out a small amount of coal in each shift'⁴⁹. However, the problem may have been in their 'situation' rather than their length, for 250 yards (229 m) was thought to be too short to make horses worthwhile at Lassodie, partly because the route led to a limited area of coal⁵⁰. Writing of Wemyss in 1845, Cadell noted that workings were 'a great way' from the pit bottom at 240 fathoms (439 metres), and proposed to make provision for a new pit during his next visit⁵¹. This helps to confirm the Halbeath figure of some 450 metres being the normal maximum for underground haulage by horses during the first half of the nineteenth century. Notable among the improvements which made feasible the longer underground hauls of the mid to late 19th century was the almost universal adoption of underground railroads.

While underground railway development is closely associated with the use of horses for haulage, it is not uniquely so, for rails also made much easier the putting of formidable loads by human muscle-power. Although Row introduced 'wheel trams' to Cadham, Fife, as early as 1741, there is no evidence of rails being installed⁵², and Duckham believes that the first underground railway in Scotland was probably that built of wood at Bo'ness in 1754⁵³. Although iron railways were developed in England by the late 1760s, they were initially metal plates mounted on wooden rails⁵⁴. In the 1790s

rails made entirely of cast iron were being introduced and by the early 19th century were coming into widespread use in Fife.

For example, although Townhill trammers were working without rails in 1810⁵⁵, nearby Halbeath had (wooden?) railways in use only 2 years later⁵⁶. Balbirnie saw the introduction of railroads in 1814⁵⁷ and in 1817, Bald recommended the installation of cast iron tram roads at Fordel, so that the expensive underground horses could be sold and trammers employed⁵⁸. The same year, he saw fit to propose tram roads at Dysart, but continuing to use horses as motive power⁵⁹. Although wooden rails were still in use at Balgonie in 1819⁶⁰, by 1830:

"The whole system of bringing coals from the wall face to the pit bottom, was greatly improved by the introduction of cast-iron rail-roads, named tram roads, in place of wooden roads."⁶¹

The shift in underground haulage efficiency produced by railroads required a parallel improvement in the winding of coal up the shaft. This had come initially with the use of the horse-gin.

Two types of horse-gin were employed in Fife. The earlier seems to have been a development of the hand windlass in which this item was modified so as to allow the application of horses. The resulting 'Cog and Rung' gin consisted of a rope drum over the pit, with spokes or 'rungs' at one end. These engaged with the cogs on a horizontal wheel which was driven round by a horse harnessed to a long bar (see figure 7.5). This design had two main disadvantages. The first was that the horse track completely surrounded the pit mouth, thus interfering with banking operations. Second, Clerk points out that this machine 'has a great deal of more friction in it' and usually had cogs missing, thus producing a 'sudden jirk'⁶². Of less importance in Fife was the third disadvantage that being over

the pit mouth, the gin was susceptible to damage from pit explosions. Its main use in Fife seems to have been for drainage using the chain and buckets, and by the mid 18th century it had been superseded for winding by the 'Whim' or 'Scotch' gin - the type employed in Fife almost throughout our period. Buxton describes the whim gin as a refinement of the earlier cog and rung gin⁶³ but it seems more likely that the whim evolved from the capstan, as suggested by Atkinson⁶⁴. The gin consisted of a rope drum of large diameter mounted on a vertical axis. The ropes were led from the drum and over a pulley, so as to descend the pit, and the drum was turned by a horse or horses working on a long horizontal arm. It is perhaps best seen as an inverted capstan (see figure 7.6).

The rise and fall of the whim gin seems to span the 150 years after about 1730, when a winding horse-gin was known to have been in operation at Kirkland, Wemyss. It is not known if this was a whim or cog and rung gin, but it was certainly found more satisfactory than winding by water power, which was abandoned after a trial of some 12 months⁶⁵. This was about the same time as gins were being introduced to other Scottish coalfields. Duckham records that Clerk's first gin at Loanhead came in 1735 and gins for Kinneil were being considered in 1740⁶⁶. By the late 18th century, the winding gin was probably at about its peak utilisation and by 1830, horse-gins were only applied at collieries of small extent⁶⁷. The decline of the horse-gin may be illustrated by the example of Fordel, where in 1817, their use could be criticised thus:

"The mode of bringing the coals up the pits requires also to be improved. Only horse-gins are used here; and no colliery of the extent of Fordel can now go on in any degree comfortably in this way. Two steam, coal drawing engines would place Fordel Colliery on a footing with the other collieries upon the River, and these would reduce the expence of that department fully one half also.

Without these engines a great output cannot be effected but at a very great extra expence."⁶⁸

Nevertheless, a number remained in use in Fife at the time of the Children's Employment Commission. Indeed, at Tough, near Kirkcaldy, the installation was new, so even about 1842 it must have been cost-effective to instal a horse-gin at a new colliery, albeit employing only 29 people⁶⁹. At Cluny in the same year 66 were employed, but a horse was likewise to be found winding the coal⁷⁰. However, horse-gins were unable to compete with steam, even in comparatively shallow mines, and the latest evidence we have of a working horse-gin is at Largoward about 1880⁷¹. The process of innovation for the 24 horse-gins for which dates are available is shown in figure 7.7, where despite the small sample, a steady long-term growth may be identified. There may also be the faintest suggestion of the typical, elongated S-shape. Figure 7.8 shows the distribution of 26 known winding horse-gins and illustrates the widespread nature of the technique. Thus horse-power was used for winding over a period of some 150 years and was to be found in all parts of the Fife coalfield.

This popularity and longevity was partly due to its cheapness. A new whim gin could be erected for around £50 and would cost about £90 per year to run, but it was also popular because of its flexibility. For example, it could be easily modified for faster winding by increasing the diameter of the drum. Clerk gives a figure of 20 feet (6.1 m) for a gin at Ormiston, Midlothian,⁷² but Duckham thinks that this is on the large side. On the other hand, at Balgonie in 1785 Beaumont recommended a gin of 26 feet (7.9 m) diameter for a depth of 50 fathoms (91.5 m) but a machine of only 20 feet (6.1 m) for a depth of about 30 fathoms (55 m)⁷³. Flexibility

came also from the ability to modify the length of the 'brachium' or arm, but the evidence suggests that a length of about 30 feet (9 m) was normal. This compares favourably in leverage with the 20-foot (6.1 m) brachium noted by Clerk for the cog and rung gin of 1740⁷⁴ or the 21-foot (6.4 m) brachium for a cog and rung gin in the Dundas of Dundas muniments of roughly the same date⁷⁵.

The number of horses employed is generally thought to have been one or two, though if working a shift system the coalowner would have needed several animals. An advantage of the whim gin was that being clear of the shaft, additional levers could be added as required, but we have no evidence that such a practice was employed in Fife. Indeed, the gins at Tough and Cluny in 1842 were almost certainly one-horse machines. On the other hand, the 3 gins in use at Dysart at the time of the Old Statistical Account may well have been worked by two horses at a time, since these pits were about 60 fathoms (110 m) deep and we are told elsewhere that this depth would have needed two horses applied to the gin⁷⁶. Despite this, the depth of horse-gin winding was more restricted in Dunfermline parish by 1842, where only depths up to 20 fathoms (36.6 m) were wound by this method, steam being applied at deeper pits⁷⁷.

Although there may have been restrictions in depth, horse-gins could wind substantial quantities of coal. In order to estimate the amount wound in a year by a horse-gin we may look at two Fife examples. First, the case of Dysart in 1792 when 3 gins each produced an average of 7422 tons (7540 tonnes) per annum between 1784 and 1791⁷⁸. Assuming an average of 10 working days per fortnight and a 10-hour day, this would represent a wind of about 15.5 4-cwt (204 Kg) corves per hour. Oddly enough, 15 corves per hour is the amount wound by the 'School Yard' gin, Bo'ness, only 20

years previously. However, this correspondence must be qualified by the fact that the Bo'ness corf was 6 cwt (306 Kg) and the pit 10 fathoms (18.3 m) deeper than Dysart.

Our second example, from Lochgelly about 1800, is some confirmation of the Dysart figure. Here, a horse-gin had brought output up to 25 tons (25.4 tonnes) per day, or about 6,000 tons (6096 tonnes) per annum, equivalent to 12.5 corves per hour.

If these two examples are typical, and we have no reason to suppose that they are not, we would have a total wind of 6-8,000 tons (6096-8128 tonnes) per annum for each gin. Add to this the fact that depths could be well up to the 60-fathom (110 m) figure and we have a winding engine significantly better than both bearing pit and windlass.

As an alternative to the horse-gin, water power was sometimes applied to the winding of coal. Although Fife saw this technique employed at Wemyss in the late 17th century and again about 1730⁷⁹, no more is heard of it in this coalfield. Despite Bald's assertion in 1808 that a water wheel 'is still the cheapest and best machine for coal-drawing, where a plentiful supply of water can be got.'⁸⁰, the Wemyss machinery had given way to horse-power. Also conspicuous by its absence was the water-balance, a system by which corves were raised by the descending force of a heavy bucket of water. As a consequence, the only serious inanimate rival to horse-power in Fife was to be the steam engine.

Although the first underground haulage engine may have been installed in England in 1804, the first definite instance for which there is evidence occurs in 1812, when George Stephenson modified a pumping engine at Killingworth so it could haul coal up an inclined plane⁸¹. Becoming more widespread in the period 1820-1840, steam

haulage appeared in Fife in 1821, when at Wemyss a winning of under-dip coal in the Newton pit was gained by a high-pressure engine placed in the waste and which drew the coals up the rise to pit-bottom. About the same time, a second high-pressure engine replaced an underground horse-gin for drawing the coals from a dip winning near Wemyss harbour. This second engine illustrated a danger of underground steam power when a fire took place at the flue of the machine⁸². From an innovation point of view, the fact that Wemyss had two engines installed for haulage less than 9 years after Stephenson's pioneer work indicates again the readiness to try out new technology which seems to have been characteristic of that particularly enterprise.

Despite this early start, the innovation of underground steam haulage was to proceed only at a moderate and steady pace. It was not until 1857 that Dunfermline parish saw steam power share equally with horses the haulage of coals underground⁸³. Allied initially with the inclined plane, steam haulage generally employed engines of comparatively small power. For example, at the Albert pit, Halbeath in the late 1850s an engine of only 10 horse-power raised the coal from the dip incline, while at Cuttlehill a similar task was performed by an engine of 20 horse-power⁸⁴. Inclined planes were not always seen as advantageous, however. Wallace and Williamson, reporting on Fordel in 1869, thought that there were too many in the pits:

"Inclines are very well where they cannot be got rid of owing to the steepness of the strata or where a large quantity of coal can be concentrated at the top, but whenever the quantity of coal coming down them is small, they tell heavily upon the oncost"⁸⁵

Improved haulage systems being developed in the mid 19th century led to the employment of steam power on level roads, thus competing with

the ubiquitous pit-pony. A good example occurred in 1873, when Mr. Carlow of the Fife Coal Company arranged for a pit-bottom engine in No 1 Pit, Kelty, to operate an endless rope for haulage, thus doing away with pit ponies on that roadway⁸⁶. Horse-haulage survived, however, and in 1901 Durland could refer to drawers, ponies and steam haulage all being employed at the Aitken pit:

"On long wheel braes, where there is a distinct gradation, the endless cable system is used for running the hutches back and forth, up and down, and on long levels where it is possible ponies draw the loaded hutches in long trains or races. Drawers push the hutches one at a time from the face where they are filled to the main levels or wheel braes where they are formed into races and sent to the bottom."⁸⁷

The substitution of steam power for horses was more complete than this in the task of winding.

Duckham has suggested that Scotland's first steam winder was erected near Bo'ness between 1777 and 1790⁸⁸. Despite Lord Dundonald's 1793 suggestion that steam power might be substituted for bearing, it was the second decade of the 19th century before we see any hard evidence of steam winding in Fife. At Dysart in 1817 we find that a gig engine employed for drawing coal was powerful, in good condition, and capable of drawing an increased output⁸⁹. Since these coals were drawn by 3 horse-gins in 1792, the steam winder must have been installed during the intervening 25 years. It is also in 1817 that we find Bald lamenting the use of horse-gins at Fordel and making his recommendation for two steam winders⁹⁰.

By about 1840, the innovation of steam winding-engines in Fife had made considerable progress. For instance, Cadell's reports on Wemyss colliery during the 1840s show ample evidence of steam winding⁹¹, and Chalmers' figures for Dunfermline parish in 1842 show a similar advancement. Of a total of 17 steam engines

employed there, no fewer than 15 had a winding function. Of these, all but 2 were of the high-pressure type⁹². It is worth reminding ourselves here that although steam engines were applied in deeper shafts as being 'more expeditious and economical'⁹³, they did not entirely replace the horse-gin, which continued in use in shafts of less than 20 fathoms (37 m). This 'cut-off' depth for steam winders in the 1840s obtains some confirmation from the 23-fathom (42 m) pit at Blair in 1843⁹⁴ and the 28-fathom (51 m) pit sunk at Kellie in 1847, both of which were steam wound⁹⁵. Even in the deeper pits, however, these steam engines remained comparatively low-powered, with a mean of 20 horse-power in Dunfermline about 1842 and still only 25 horse-power in 1857. Even later in the century, small engines were occasionally used, such as that at Lochore in 1872⁹⁶. The late 19th century saw a huge increase in the power of steam winding engines, but horse-power figures are not always available for Fife. However, some estimate of their capabilities may be made by looking at the amounts raised.

At Kelty about 1870, for example, one loaded hutch of 5-6 cwt (254-306 Kg) was drawn each wind, while less than 30 years later, the Aitken pit saw 4 hutches, each of 10 cwt (508 Kg), drawn from 203 fathoms (371 m) in only 32 seconds⁹⁷. By 1900, Lumphinnans No 11 pit was being fitted with cages to carry 8 hutches, each of 12½ cwt (637 Kg) - a total of 5 tons (5 tonnes) of coal in each wind from a depth of 200 fathoms (366 m)⁹⁸. Clearly, such impressive power could not have been applied to corves dangling from unreliable hemp ropes, and the development of steam winding on this scale depended as much on the improvement of the shaft fittings as on the increased power of the winding engines themselves.

One of the first improvements to be introduced was by Curr, who pioneered the use of guides in 1787. The corves were suspended from cross-bars which fitted on to wooden guide-rails attached to the shaft walls. There are no references to this technique in Fife, and it seems likely that the simpler plan of vertically dividing the pit was applied in the county, where it had the additional advantage of being an aid to ventilation. Much more prominent in Fife mining technology was the development of winding in cages. Initially invented by Hall in 1834, sliding cages were employed in Wellwood, Dunfermline, by 1842⁹⁹. Within 15 years, several other Dunfermline collieries had taken up the idea, which suggests that the 1840s and 50s were years of diffusion. Some confirmation of this view is found in Cadell's recommendations at Wemyss in 1845 and 1846¹⁰⁰, where he thought the use of cages with slide rods would be highly advantageous, and included a sketch for the engineer (see figure 7.9).

The use of high-speed cages was made possible partly by the replacement of hemp ropes with wire. First tried out elsewhere in 1829, wire ropes were widespread in the Fife coalfield by about 1860, although had not entirely superseded hemp. In 1857, Townhill and Whitefield collieries had some pits winding with wire rope, others with hemp¹⁰¹. Flat ropes, made by stitching four ropes together, were favoured by Bald in 1830, their great advantage being that:

"by lapping upon themselves, they act as a compensation or balance against the weight of the descending corve and rope"¹⁰²

Unfortunately, we cannot be clear as to whether the flat or round rope was favoured in Fife.

The closing decades of the 19th century have less to show in terms of technological innovation. Although improvements continued to be made in haulage and winding, and the introduction of electricity made

some headway before 1914, none of these changes were revolutionary in nature or consequence. Compressed air appears to have made little progress in Fife haulage systems, and electricity doesn't feature until about 1905, when it was being installed for haulage in the Nellie pit, Lochgelly, and at the nearby Minto colliery¹⁰³. The Aitken, sunk in 1897, used electricity for pumping and haulage 'at a comparatively early stage of the development'¹⁰⁴, but winding remained overwhelmingly a steam-powered activity until well after the Great War. Haulage, on the other hand, saw one further modification before 1914. In 1902 Blackett invented the first successful coal-face conveyor, which consisted of an endless chain carrying scrapers which moved the coal along a steel trough. Only 3 years later, Lochgelly saw one of these in use¹⁰⁵, and by 1912, conveyors were installed also at Kinglassie and Aitken pits¹⁰⁶. A detailed study of the innovation of this particular machine would throw considerable light on the role of the coal companies in technological change and could be a worthwhile focus of further research.

Our more general picture, however, has now taken form. It is one in which haulage and winding innovations have been linked with new power sources, and the techniques associated with them. The progression from manual labour to horses, steam and then electricity is not one of 'replacement', however, but one in which there is considerable overlap. In the 1840s, for example, we find evidence of bearing, tramming, horse-haulage, steam-haulage, horse-gins and steam winding all operating within a few miles. The situation was an evolving one, though, and soon reflected the dominance of steam, without which the haulage and winding 'bottleneck' could not have been successfully overcome.



Figure 7.1

BEARING

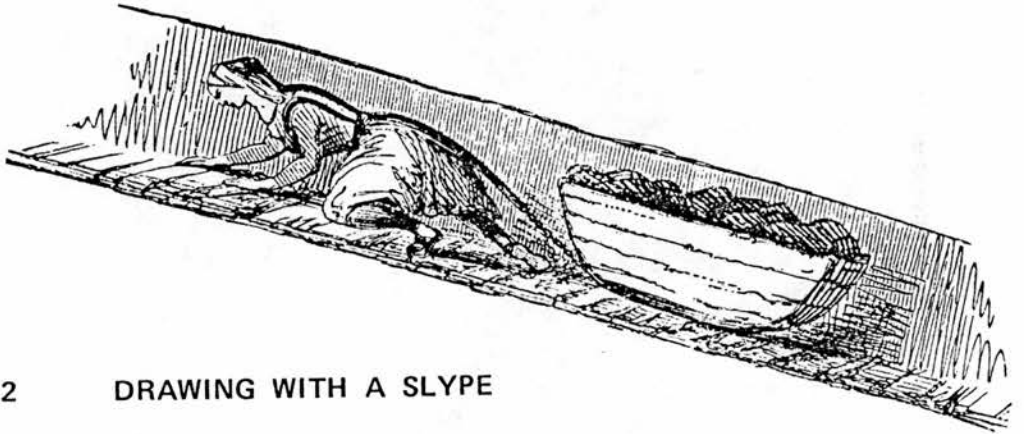


Figure 7.2

DRAWING WITH A SLYPE

Figure 7.3

DRAWING WITH A HUTCH



Figure 7.4
ESTIMATED NUMBERS EMPLOYED IN UNDERGROUND HAULAGE
AT 29 COLLIERIES (1842)

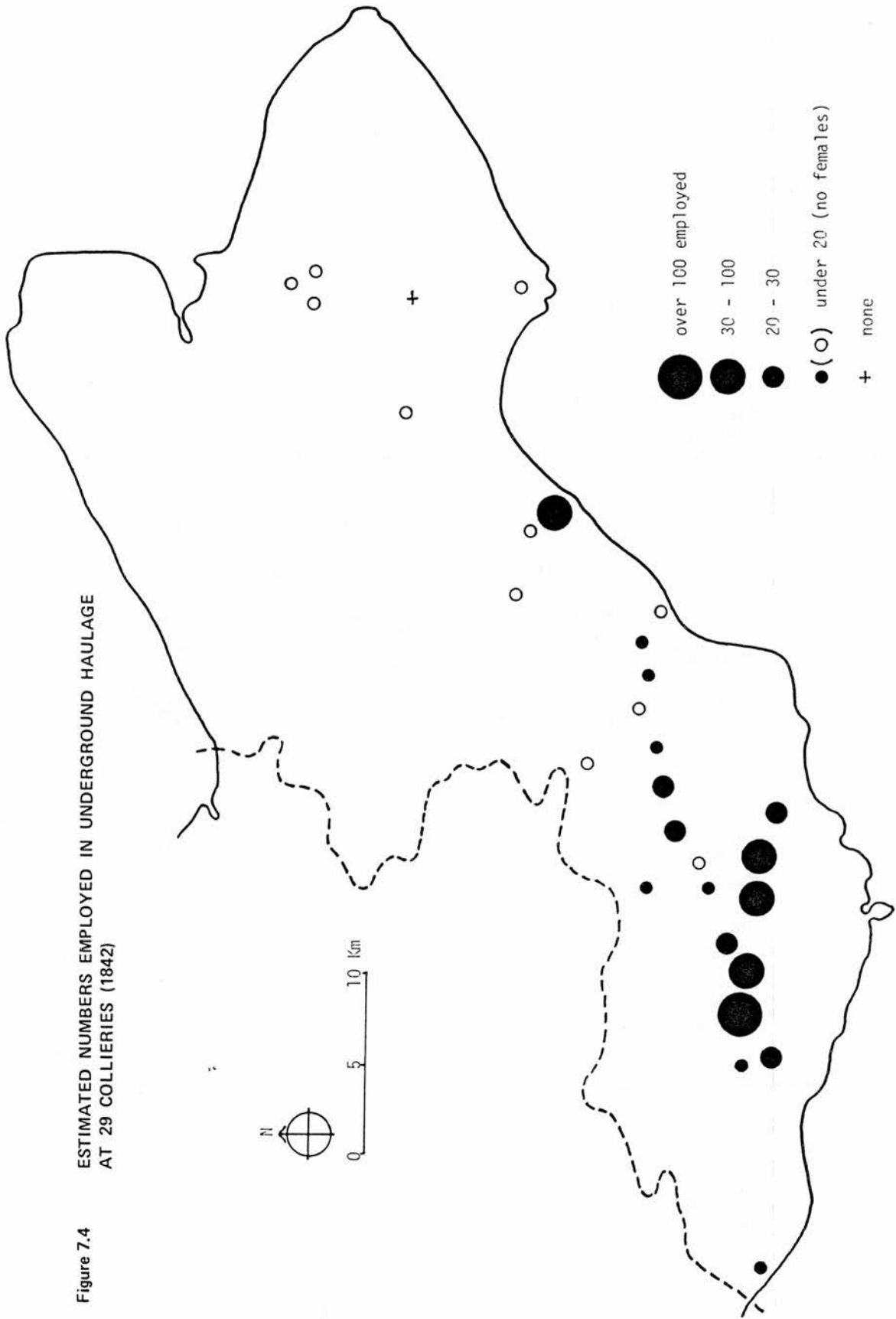


Figure 7.5 COG AND RUNG GIN (1740)

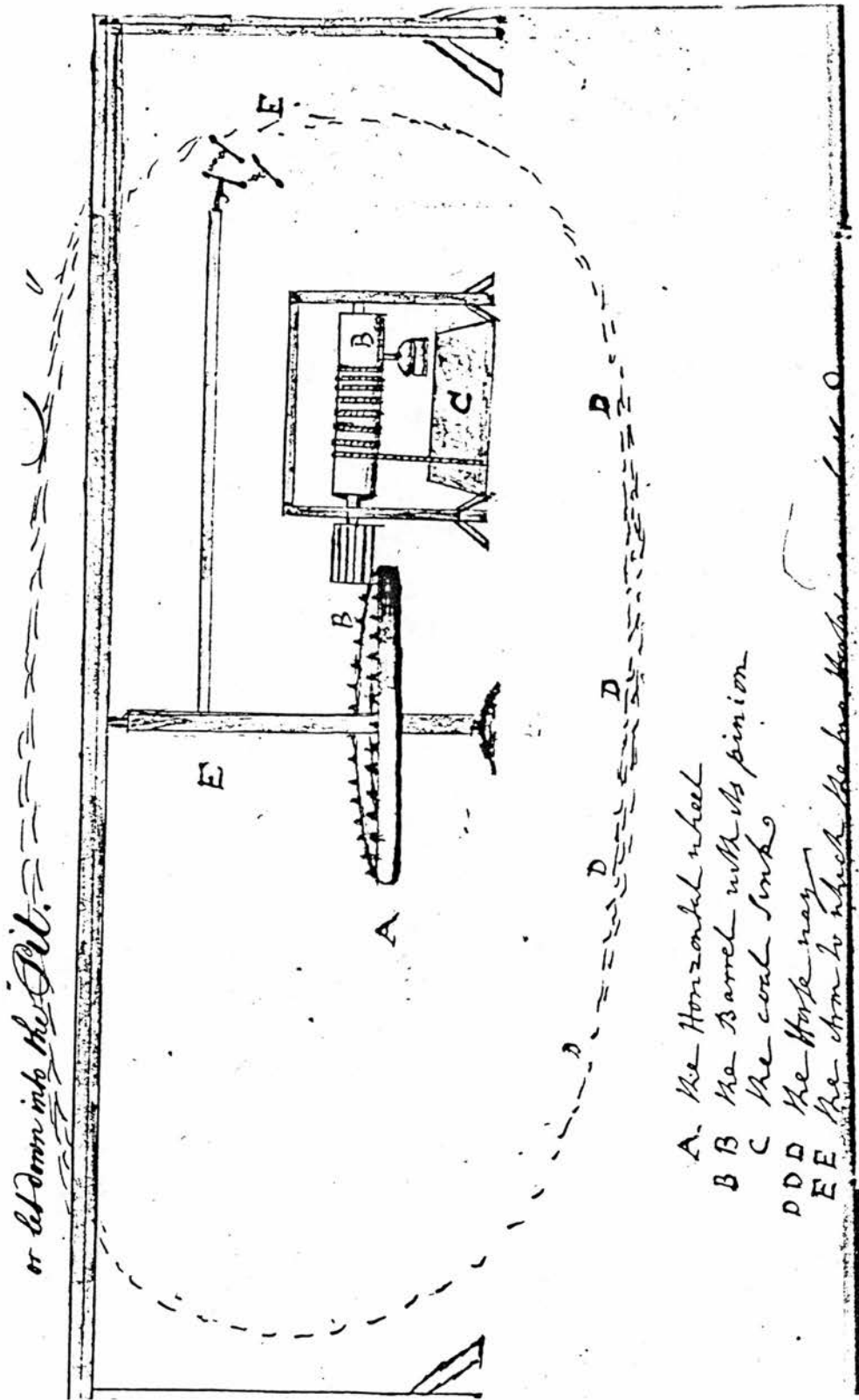
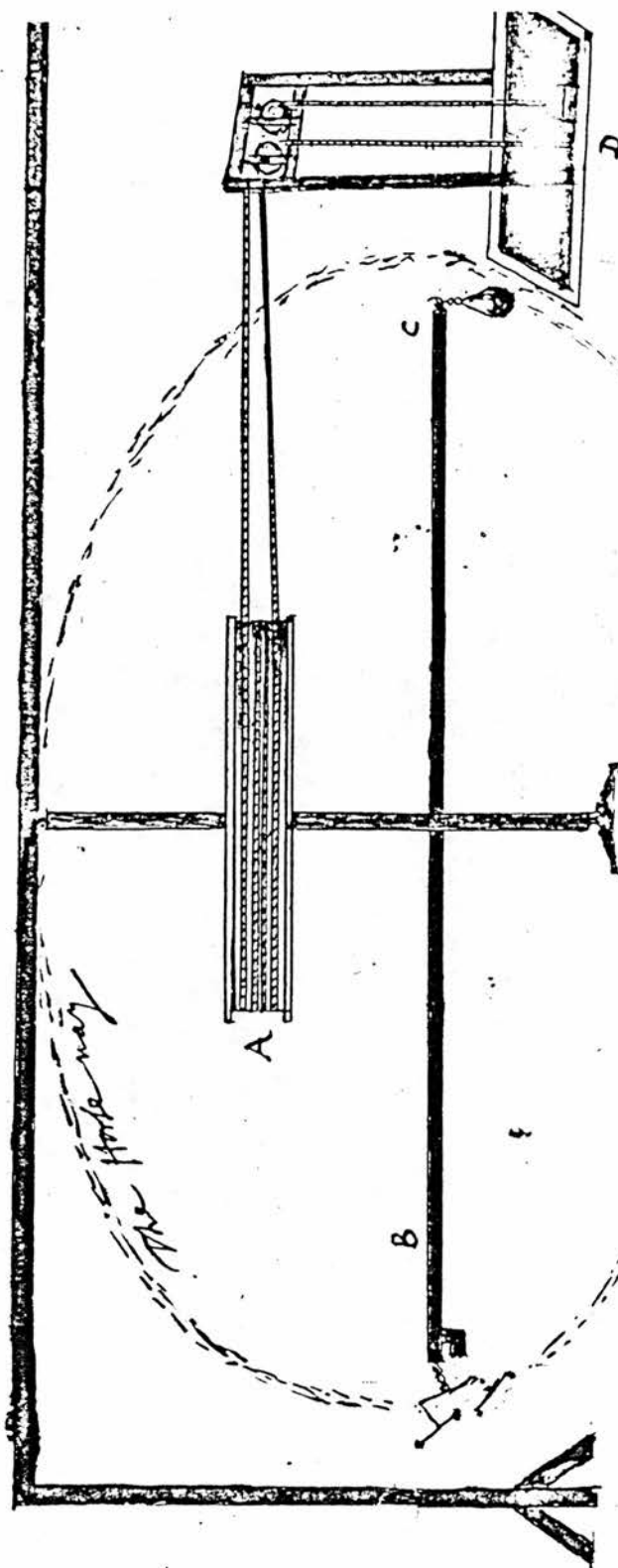


Figure 7.6 WHIM GIN (1740)

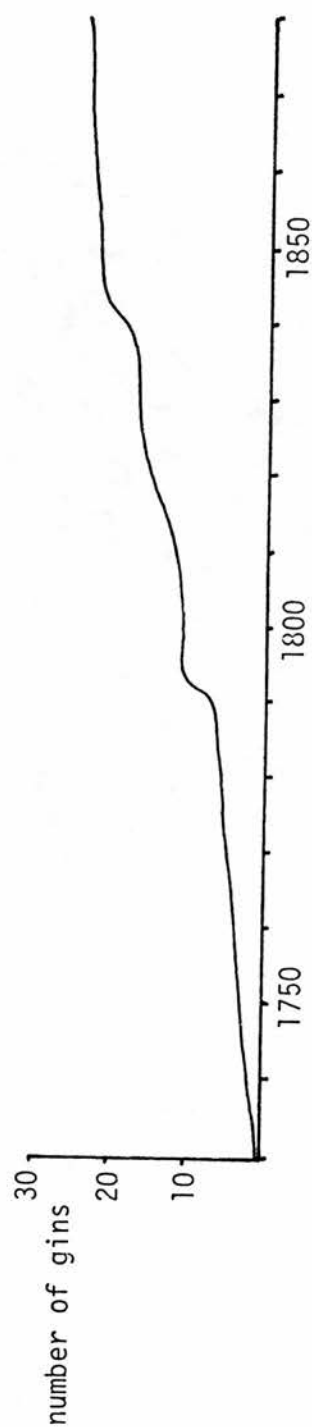


A the Barrel
B the Brachum to
the horses are fasten
C another Brachum
somebody a nagle
to fasten the
D

The Horse may
Brachum B is somebody placed a seat
where the Driver sits but commonly the Driver
goes on foot to fasten the rope and there is no
Counter Brachum and fallagee.

0.0 . 0.0 . 0.0 .

Figure 7.7 INNOVATION DATES OF 24 WINDING HORSE--GINS (1730--1880)



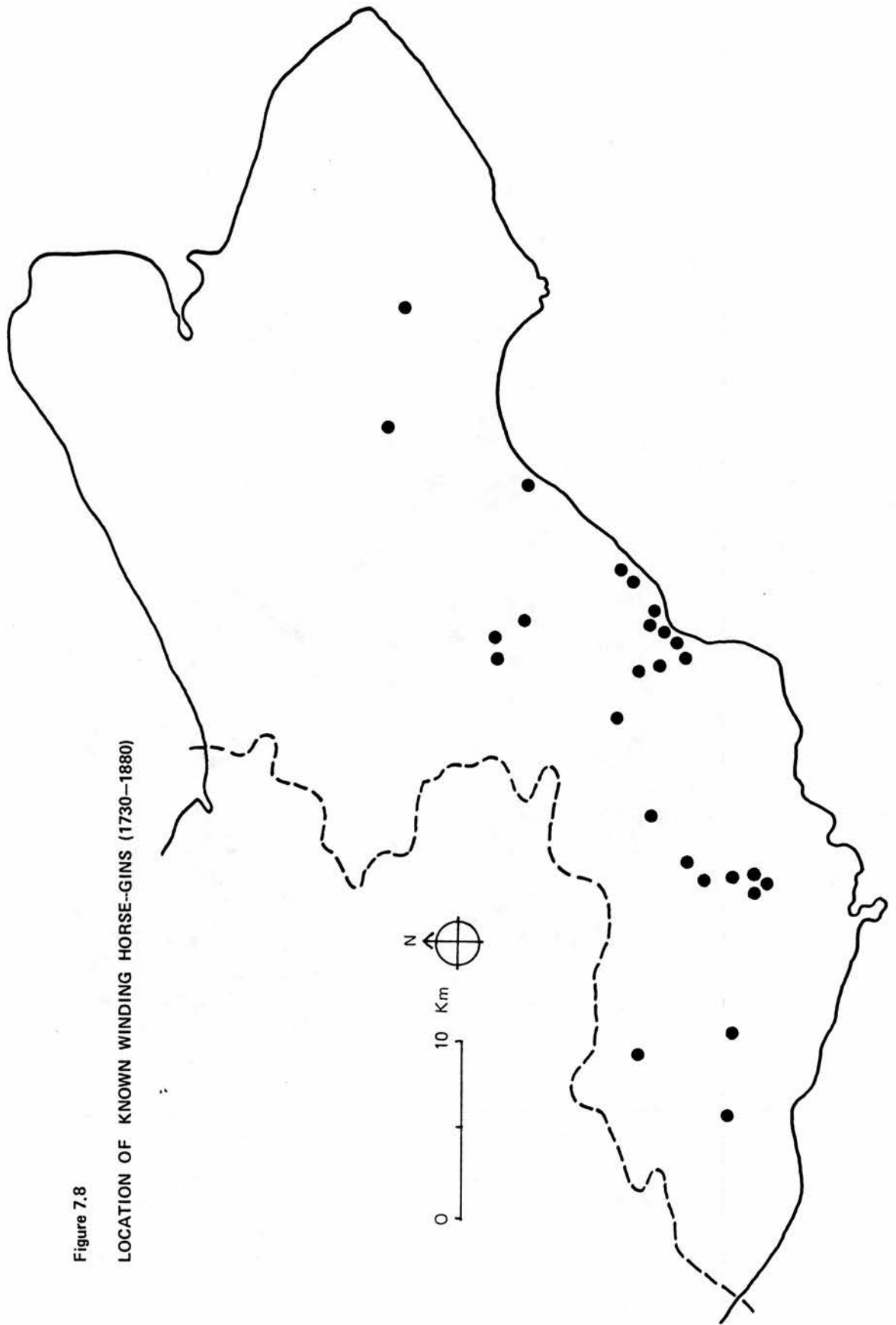
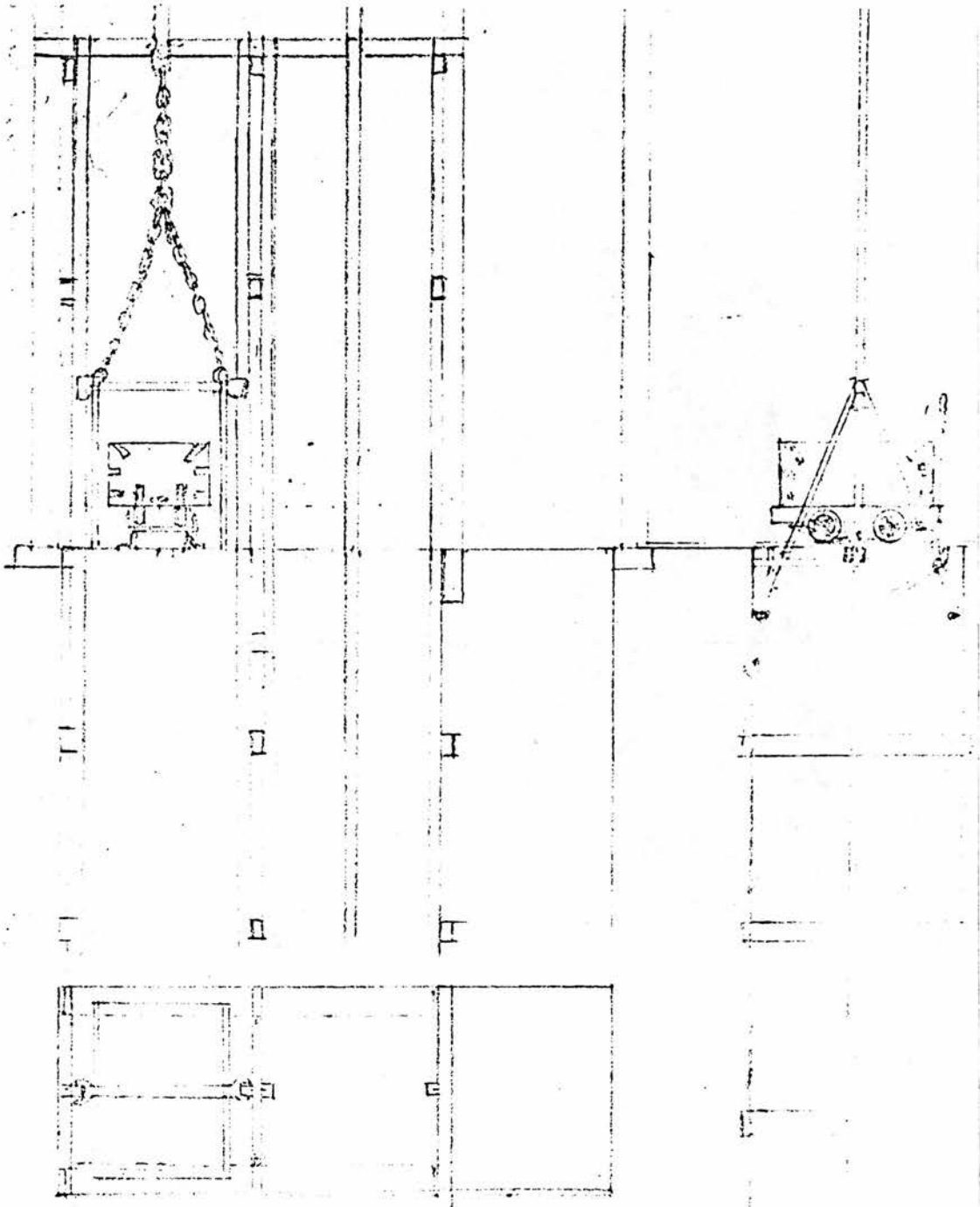


Figure 7.9 CADELL'S SKETCH FOR PROPOSED CAGES AND SLIDES AT WEMYSS (1845)



CHAPTER 8 - TRANSPORTATION AND MARKETS

As the major force in Fife's regional development, the coal industry was closely related with the improvement of transport in the county as well as with the growth of coal-dependent industries. We will examine the transport aspect by looking at the development of coal carriage from the packhorses of the seventeenth century to the dense railway network of the early twentieth century. We will see how these routes were to a large extent determined by the need to carry coal to the coast for shipment, where a large number of small harbours eventually came to be dominated by Methil and Burntisland. The shipping market is then put in context with the coal demands within Fife itself - the household market and the salt, lime and iron industries. In this way it is hoped to clarify at least to some extent the complex web of relationships within which the dominant coal industry influenced the changing economic geography of Fife.

Overland transport

In the seventeenth and early eighteenth centuries the poor state of the roads made them virtually impassable in bad weather, so packhorses were often employed. Thomson believes that Rothes coals were transported by this method in 1741, when Row instructed that 'a sufficient place of ground be staked out at the coalhill and stakes driven in at different places for fastening the halters of the horses that are for coals.'¹ However, there is also an undated calculation from about the same time which looks at the cost of using six one-horse carts to carry coals to Kinghorn, each cart making two trips a day². Row's instruction might possibly have applied to horses which pulled carts rather than to pack animals, but we cannot be certain.

Although packhorses were still used at Fordel in the early 1750s, there are no later references to this form of transport, which is possibly a reflection both of the improvements in Fife roads which took place after mid-century, thus allowing the easy transport of coal by horse and cart, and of the increasing quantities of coal being moved overland by waggonways. In looking at carting it is convenient to consider first the distances covered, second the loads carried, and finally the costs of this form of transport.

While recognising Duckham's view that for Scotland as a whole the average economic carting distance in most coalfields was not above six miles (9.7 Km), there are several Fife examples where this distance was exceeded³. For instance, the 1740 estimate from Rothes is with reference to Kinghorn, where the journey could not have been less than 11 Km. By the 1790s, Cults parish obtained coal from Balbirnie and Balgonie, which were respectively about 10 and 13 kilometres distant⁴, while Ferry-Port-on-Craig was partly supplied overland by carters who had driven a distance of about 16 kilometres⁵.

By 1836, Newburgh parish was getting coals overland from Balgonie (21 Km) and Lochgelly (32 Km). This must have been dependent on road improvements having taken place since the time of the Old Statistical Account, when the area to the South of Newburgh was 'badly provided with roads'⁶. About the same time, Balmerino - situated on the Firth of Tay - sometimes got its coals overland from the Southern part of Fife, the nearest pits being some 19 Km away at Drumcarro. However, this does not seem to have been a commercial operation since the occasional carting was done by farmers to supply themselves and their servants⁷. How far this kind of thing was due to the improving quality of the roads, particularly turnpikes, is

well illustrated by a report on Powgild, Lochgelly, in 1820. Here, it was calculated that a projected turnpike road through the estate would increase sales to such an extent that it might raise the fixed rent obtainable for the minerals by as much as 100%⁸.

Although we might suppose that improvements such as this would increase the loads carried, we have little evidence with which to test our supposition. We do know, however, that the Dysart coals were in 1817 drawn to the harbour in loads of only 10 cwt (0.5 tonnes), and this was felt to be 'tedious and expensive' since the road was downhill and a horse could easily have drawn twice this amount⁹. Heavier loads must have been common in Auchterderran parish about 1790, when the carts were all drawn by two horses¹⁰. One possible explanation for the carting of light loads was the fact that many carters were only part-time. They were actually tenant farmers who used their farm carts and horses in the coal trade as a source of extra income, so their carts were designed for agricultural work rather than the transport of minerals over long distances. For example, Thomson believes that the 'Kinghorn' calculation of about 1740 represents an attempt by the Rothes estate to overcome some of the limitations of transport by tenants, and the Old Statistical Accounts for Crail and Ferry-Port-on-Craig both refer to the use of farmers' carts for transporting coal¹¹. Nearly half a century later, the practice was still to be found in the parish of Cults, where tenants of small farms 'but for the carting of coal and lime, would not afford sufficient work for their horses.'¹²

The costs of this kind of system were bound to be high compared with, say, a proper waggonway, and indeed they were. At Halbeath between 1802 and 1812, the carriage of landsale coal nearly doubled

the hill price of the mineral¹³. Generally, the figures for Fife correspond quite well with those given by Duckham for Ayrshire, so are probably not exceptional¹⁴. For example, the cost of bringing half a ton a distance of one mile (1.6 Km) works out at about 3½d in Cults in 1792¹⁵, 4d in Carnock during 1794¹⁶, 5d at Dysart in 1817¹⁷ and 4d at Brucefield in 1821¹⁸. At Dysart, it was thought that 30-40% saving could be effected by having the horses pull loads of 20 cwt (1.02 tonnes) instead of 10, with an even greater improvement if a cast iron railway (waggonway) was adopted¹⁹. Nearly 40 years later, carting was still being employed at Methil where it cost 1s 2½d per ton to cart the coal just over a mile to the harbour. It was calculated that a tramway would save about 9d of this charge, thus reducing the carriage element in the 'harbour' cost from 18.5% to 7.4%²⁰. Although this kind of improvement was responsible for the development of waggonways, carting could still be found in Fife even in the late nineteenth century. In 1872, for instance, Capledrae colliery was still dependent on carting for sending out minerals, although by this date a scheme was afoot to provide it with a railway link²¹. Even as late as 1892, small amounts of coal were being carted from the pits at Kinnedar and Blair. This was carried out at great expence in advance of a railway connection being made so that a market for the coals might be established, and carting ceased in July, 1892, when the railway took over²². However, older collieries had long since seen carting superseded by waggonways in a process of innovation which had begun in the mid eighteenth century.

For waggonway development, the initial requirement was to have heavy coal traffic on one particular route over a moderate to long distance, perhaps 2-5 miles (3.2-8 Km). This condition was fulfilled

where an inland colliery was producing substantial amounts of coal for sea shipment, so that an easy route to a nearby harbour was desirable. This was true of all four of the major waggonways in Fife - Elgin (1768), Halbeath (1783), Fordel (1769) and Wemyss (1789) - but not so characteristic of the less well-known routes developed mainly in the early or mid-nineteenth century and which sometimes appear in the First Edition of the Ordnance Survey as 'tramroads' (for example, at Lochgelly, Cowdenbeath, Dundonald). In order to investigate the role played by waggonways in developing the Fife coalfield, we will examine their major technical improvements. First, we will look at the change from roads to permanent wooden rails. Second, the introduction of iron rails will be considered. Third, the method of traction will be examined, including inclined plane, horses and the steam locomotive, and finally we will try to identify how far these changes were able to reduce the costs of transport, an area in which the horse and cart had been relatively unsatisfactory.

The innovation of railed waggonways was brought to Scotland by the York Buildings Company in 1722, when their pits near Tranent in East Lothian were linked with the harbour at Port Seton. However, it was over 40 years before the idea was taken up in Fife. Admittedly, the Fordel ('coal road' was extended to St David's about 1752, soon after the construction of a harbour and saltpans there, but this was simply an extension of packhorse transport, and a railed waggonway seems not to have been built until about 1769, certainly appearing on Ainslie's map of 1775²³. A reference to 'wagon roads' in the vicinity of Leven in 1760 may indeed be to roads or may be to a wooden waggonway, but in the absence of further evidence, we cannot be certain²⁴. On the other hand, we can be fairly sure that the Elgin

waggonway was begun about 1768, but by 1773 seems to have stretched only from Limekilns to Pitferrane, since at that date it was proposed to continue it as far as Balmule²⁵. This illustrates the process by which eighteenth-century waggonways were built. Growth and development were linked with the changing pattern of activity in the group of collieries served. This feature is particularly evident at Elgin, Halbeath and Fordel. For example, the Halbeath waggonway was laid between 1781 and 1783 to carry coal from the pits to the harbour at Inverkeithing, some 5 miles away (8 Km). A branch from Townhill colliery (known as the Townhill Tramway) was constructed in 1841 to join the waggonway at Guttergates, although the financial advantage of a scheme such as this had been recognised as early as 1810, when a report on Dunfermline Town colliery (Townhill) remarks:

"...and the only great drawback, and a great drawback it is, is the expence of leading the coals to the shore.... the only persons who can work it comfortably, and to advantage, are the Halbeath Company, with the aid of their waggonway which would reduce the price of leading to a mere trifle"²⁶

In the development of branch lines to serve new pits, the Fordel Railway is perhaps the most spectacular example, extending nearly six miles (9.7 Km) inland from St David's and not having its network completed until 1895 (see Fig. 8.1). On a more modest scale, a two-mile waggonway had been built at Methil by 1789²⁷ and a map of that year also shows one at Pittenweem²⁸. Leven, too, had a wooden railway, the route of which is shown on the Ordnance Survey map of 1854, and by the mid nineteenth century, no fewer than 15 waggonways and 'tramroads' had been built (see fig 8.2). In six of these, the aim was to carry coals to a harbour for shipment, and an additional proposal for Dysart in 1817 also had this purpose in mind²⁹. Seven were 'tramroads' which connected collieries with nearby railway lines, while of the remaining two waggonways, that at Brucefield before 1821

was built to carry coal to the Kilbagie distillery, thus avoiding tolls payable under the carting system³⁰. That at Venturefair was erected in 1812 to bring coal to the urban market of Dunfermline³¹.

The waggonways built in the eighteenth century were all originally of wood, and for this reason were easily damaged and difficult to maintain. The poor wearing quality of fir is pointed out in the New Statistical Account for Alloa, Clackmannanshire, where double rails of this type were soon chaffed and worn by the iron waggon wheels³². A solution to this problem was to replace the upper rail with beech, and this was the answer adopted at Fordel³³. Despite this, maintenance costs remained as high as £560 per annum in 1798 due to the horses damaging the lightweight sleepers and the practice of 'spragging' - braking by pushing a wooden bar through the iron wheel spokes³⁴. This sort of figure receives some confirmation from an estimate by Bald nearly 20 years later in which he puts the cost of wood and workmanship at £4-500 or more per annum³⁵.

Although the Alloa waggonway had iron plates laid over its wooden rails in 1785³⁶, the full-scale substitution of iron for wood in Fife had to wait until the turn of the century and it was 1811 before this innovation took place. About that year the Halbeath waggonway was laid with cast iron rails but there seems to be some doubt about the dating of iron rails on the Elgin waggonway³⁷. Although Dott and Dendy Marshall strongly imply 1821, Duckham's suggestion of 1812 seems more likely, backed up as it is by Fernie's comment of 1815³⁸. Certainly, an iron railway was proposed for Dysart in 1817³⁹, and by 1821 another had been actually built at Brucefield in the extreme West of the county⁴⁰. Surprisingly, it was 1833 before iron rails were adopted at Fordel, where a section of wooden track remained in use for a further two years⁴¹. This is surprising because substantial

benefits in both effectiveness and costs were to be gained by the innovation, and Bald had suggested an iron railway here in 1817, when he thought:

"an improved iron rail-way, and waggons of smaller size would not only produce a great saving of expence, but a greater quantity could be led to the shore every day."⁴²

The accuracy of this remark is proved by the fact that it was precisely these benefits being enjoyed by the nearby Halbeath iron waggonway which was instrumental in Fordel's use of iron rails from 1833. By 1826 the Halbeath route showed only about half the running costs and one-eighth the maintenance costs of Fordel, despite the fact that it was roughly the same length and had steeper gradients⁴³. Within 10 years, though, the New Statistical Account could report that

'extensive operations have been going on for some time, preparing a new line of road for an iron railway, which, when finished, will be an immense saving annually, independently of the greater facility and expedition with which shipments may then be made.'⁴⁴. After these improvements, the Fordel waggonway was able to carry nearly double the quantity of coal for one third the operating costs of the wooden track. Admittedly, other changes were carried out at the same time as the iron rails were laid, but there is ample evidence elsewhere of the savings to be made by this innovation alone. At Alloa,

Clackmannanshire, for instance, a horse could haul 160 cwts (8.13 tonnes) on a cast-iron 'edge' railway, compared with only 30 cwts (1.52 tonnes) on a wooden waggonway⁴⁵, and in Dunfermline parish in 1815, cast-iron railways are said to have saved the labour of no fewer than 100 horses⁴⁶. At Fordel, however, the improvements begun in 1833 included three inclined planes, which reflects the importance of a favourable slope for a horse-drawn railway.

Although the waggonways are too few and the variables too many for us to make much of 'average' gradient, it is a coincidence worthy of comment that the three best known waggonways of Elgin, Halbeath and Fordel at first ran comparable distances to the Forth from collieries situated about 120 metres above sealevel. Consequently their average gradients are fairly similar, at 1 in 53, 1 in 46 and 1 in 59 respectively. It may be that these gradients were scarcely gentle enough, for Fordel - at only 1 in 59 - met with this comment from Bald:

"In order that a colliery waggon-way, such as Fordel, may be most effective, the whole line requires to be on a descent to the harbour, and of such an inclination that the horse may, with ease pull back the same number of empty waggons, as he brought down loaded. To bring Fordel waggon-way, into this state, will require considerable labour...."⁴⁷

At some places, gradients were much steeper than the average and in this event self-acting inclines could be employed. Such was the case at Fordel (where 4 inclines were eventually employed), Elgin (3) and Lochgelly (1). The gradients on these inclines varied from 1 in 20 to 1 in 28 and the full waggons running downhill were sufficiently powerful to raise the empties via a rope or wire wound round a wheel at the top of the slope. A good example is that at Vantage, Fordel, where in 1838 the wheel was raised to be in line with the rope and thus increase its mechanical efficiency (see fig 8.3)⁴⁸. In only one location was the gradient against the direction of the load, and this was a stretch of Fordel waggonway near Hillend. Bald felt in 1817 that a cutting would be useless here and a tunnel too expensive, so he suggested installing a stationary steam engine to pull the loaded waggons up the slope⁴⁹. In 1830, the idea of a cutting was again rejected, this time on the grounds of being both unnecessary and expensive and in what seems to be a much simpler solution, Gofton

proposed in 1832 that an extra horse be stationed at Hillend to help on the slope⁵⁰. Eventually, however, a cutting and short tunnel were adopted after an examination of the line in 1834 by Robert Hawthorn of Newcastle.

The introduction of locomotives to Fordel in 1868 necessitated the reduction of the inclines, and those at Colton and Vantage were altered, leaving the St. David's incline to continue in use for gravity shunting. On the Elgin Railway, the inclined planes were in use from 1821 and a flat area utilised by building an embankment with two lines on different levels, so that there was a gentle declivity in both directions⁵¹. By 1859 a third incline had been added near the shore. At Lochgelly, too, a self-acting incline ('wheel brae') was in operation by mid century. Here, the waggons were drawn by horses from the Jenny Gray pit to the top of the incline whence they were run down to the main railway line and iron works⁵².

The fact that the slope favoured the loaded waggons was a big help in terms of the amounts carried, and we may look to Fordel for an illustration. Before the first waggonway, we do not know how much a horse could pull down the Fordel 'coal road', but it is unlikely to have been more than 10 cwts (0.5 tonnes). At Alloa, Clackmannanshire, the comparable figure was 6 cwts (0.3 tonnes) and we have seen that even by 1817, Dysart carts carried only 10 cwts. The building of the wooden waggonway at Fordel made a considerable difference and by 1794 a waggon normally contained 48 cwts (2.44 tonnes) of coal⁵³. Waggon were the same size when Bald reported on the colliery in 1817 but a greater weight was frequently loaded⁵⁴. Dott's figure of 4 tons (4.06 tonnes) per waggon on the wooden waggonway is possibly erroneous⁵⁵. In recommending an iron railway, Bald also thought that smaller waggons would be cheaper and would allow a greater quantity of coal to be led

to the shore each day. The reason for this is that a larger number of waggons would be pulled, the impetus of the first helping to shift the second, and so on⁵⁶. By the 1830s, waggons of 60 cwts (3.05 tonnes) when loaded were in use, though still on the wooden track⁵⁷, and a horse could draw three of these, or 9 tons (9.14 tonnes) in all. In Gofton's plan of 1832 he proposed waggons weighing 18 cwts (0.91 tonnes), each holding $2\frac{1}{2}$ tons (2.54 tonnes) of coal. A horse could draw four of these, or nearly 14 tons (14.22 tonnes)⁵⁸.

The weight of waggons was still a problem in 1869, when John Williamson the mining engineer found them to weigh almost 30 cwts (1.52 tonnes) each, with a load of only 57 cwts (2.9 tonnes). At other pits nearby the figures were 10 cwts (0.5 tonnes) carrying 33 cwts (1.68 tonnes) and 13 cwts (0.66 tonnes) carrying 45 cwts (2.29 tonnes). This means that 34% of the horse's work at Fordel was expended in hauling only the waggons, compared with 23% and 22% elsewhere. The haulage of the extra dead weight was considered 'somewhat excessive' at Fordel, especially in view of the inclines up which the empty waggons had to be drawn. However, this problem was by then less serious since a locomotive had been introduced in 1868 so that there was power to draw as many as 34 empty waggons up the railway⁵⁹. Despite this problem of weight, the total tonnage carried was substantially increased by the innovation of the iron railway and associated easing of gradients. A figure of 34,000 tons (34,544 tonnes) in 1791 had risen to about 50,000 tons (50,800 tonnes) in the late 1830s. While this was scarcely 'nearly double' it was nevertheless an invaluable improvement⁶⁰.

Of course, the motive power at that time was still provided by horses. Sometimes waggons were drawn by two animals instead of just one, and the close of the eighteenth century saw over 50 employed on

the route, with 30 waggons. Most of these animals were contracted from local farms, and in a letter of 1788 to Sir John Henderson in London, James Pinkerton illustrates the sort of problem which could arise:

"Our shipping still continues brisk - but the labour having now commenced after being long kept back with the bad weather, I shall have great difficulty to get the coal drove down as all the Tenants are for taking off their Waggon Horses for their Ploughing."⁶¹

At Halbeath about the same time, 24 waggons were employed, drawn - as at Fordel - by one or two horses, and implying perhaps 20-30 animals in use⁶². By 1844 the waggonway employed only 15 beasts, probably due to the effectiveness of the iron line where in 1832 a horse could draw 18 tons (18.29 tonnes) a day compared with 8½ tons (8.64 tonnes) on the wooden track at Fordel.

The introduction of locomotives, to Elgin in 1852 and to Fordel in 1868, brought two major developments. First, it improved enormously the haulage power available to the waggonway proprietors and second, it helped to reinforce the integration of some tracks with the growing railway system in Fife. In 1859, the Elgin Railway saw inclined plane, horses and locomotives all employed in the haulage of coal on different parts of the track⁶³. Fordel, however, was slower with the introduction of locomotives, with its first in 1868, its second in 1871 and a third in 1880. Halbeath never introduced them at all, despite its earlier use of iron rails, and in 1847 was actually still using birch logs to drag as waggon brakes⁶⁴. It was closed in 1871. Locomotives required a considerable investment, since gradients had to be reduced and track strengthened, in the case of Fordel by second-hand rails from the North British Railway. Although some doubts were expressed at the wisdom of this programme, both by Williamson⁶⁵ and by the auditors⁶⁶, its success is verified by the

fact that the Fordel Railway continued in use as a private railway well beyond the end of our period. The Elgin Railway survived first by amalgamation with the West of Fife Railway and then by being taken over and only partially closed by the North British Railway in 1862. In this respect the Elgin Railway reflects the more general picture in West Fife, which was of main line railways superseding the original waggonway routes. The pits in the Halbeath area were eventually connected with Charlestown harbour via Townhill and the Elgin Railway, which itself had a junction with the Stirling and Dunfermline Railway. The Fordel pits, though the railway was the wrong gauge for integration, had by 1853 a connection with the Edinburgh, Perth and Dundee Railway which ran a little to the North of some of the later colliery developments.

We have already said enough to suggest that improved waggonways were able to make substantial savings in transport costs. For example, at Townhill in 1810, the use of the Halbeath waggonway was thought able to reduce the cost of leading to a 'mere trifle'⁶⁷, while the possible savings at Dysart were remarked on by Bald seven years later⁶⁸. Iron rails at Fordel were expected to produce an immense saving annually and did, in fact, do so⁶⁹. Such is the importance of these improvements that some cases are noted where the coal was only economically workable because of the cheap transport facility. A good example is Cuttlehill, near Fordel, which could not be profitably worked in 1793 because the proprietor had no right of way-leave or a waggonway to the shore⁷⁰. It comes as no surprise to find this property leased by Henderson of Fordel in 1798, and the waggonway quickly extended to it. A similar case is found near Berrylaw, West of Dunfermline, where:

"...it is evident that no lessee can work these coals so advantageously as his Lordship (Elgin), from his having an improved railway from this coalfield to Charleston, and an established sale upon the River Forth; without which rail-road none of Mr Allan's coal could with any advantage be shipped, as they would require to be transported by carts, and were any other lessee to attempt, a landsale of these coals, the competition with Lord Elgin's collieries adjoining, would render the adventure very unprofitable; nor do I think that the case would be better, were Mr Allan to work the coal himself."⁷¹

Although there are many references to the great expence of construction and maintenance of waggonways, there are comparatively few hard figures. The Old Statistical Account for Alloa, Clackmannanshire, puts the cost of wooden rails overlaid with malleable iron at more than £880 per mile⁷², while at Fordel about 1800 the cost of constructing only a double-railed wooden track is given as £470 per mile, but only £125 for single rails⁷³. The cost of an improved Fordel line in 1817 is estimated by Bald at £7560, or about £1500 per mile⁷⁴, a figure which is confirmed by his 1815 cost for Townhill - £1500 for a distance of not much more than a mile⁷⁵. Although a substantial expenditure for the time, these sums were considered worthwhile in view of the savings to be made in transport costs. Even later in the nineteenth century, expensive improvements continued to be made. For example, over £1735 was spent on 'upholding' the Fordel Railway between 1866 and 1868, apparently in anticipation of the introduction of locomotives. We have already noted that this item attracted some attention from the auditors and from John Williamson, engineer, who reported on the loss-making colliery in 1869. Soon after this, the construction of a tramway was one factor contributing to some serious financial problems faced by the Wemyss family⁷⁶. Quite apart from construction, maintenance costs are known to have been heavy, and perhaps the clearest statement of these is found at Fordel in 1817, where wood and workmanship were reckoned at £4-500 yearly. An iron

track, though more expensive to build, was cheaper to maintain⁷⁷.

To be worthwhile, this investment had to make a significant saving in the cost of transport, and it did. Bald saw a saving of 6d per ton resulting from the new railway, thus reducing the cost to 7d per ton⁷⁸. It is not clear whether this is cost per ton/mile or cost per ton for the whole length of the railway, but this figure for an iron track corresponds fairly well with a Brucefield cost in 1821 of less than 8d per ton/mile⁷⁹ and also with the 6½d per ton/mile paid by Spowart about 1844 for the use of the Elgin Railway to transport his Wellwood coal⁸⁰. The lower costs of the later nineteenth century are illustrated by the case of Lochore, where a tramway of 1½ miles covered all the expenses at about 5½d per ton/mile, a figure to be more than halved on the building of a branch of the North British Railway⁸¹. Clearly, this kind of improvement in costs could only have been associated with the growing use in coal transport of a major rail network.

Railways

Our aim now is to examine the relationship between the development of the coal industry and the growth of the railways in Fife. We will look in turn at three aspects of this relationship, starting with the effects that rail transport had on the economic viability of collieries. Second, we will examine the expanding network of lines in relation to colliery locations during the second half of the nineteenth century, and third, we will look at the construction of lines for the carriage of coal to shipment ports.

In terms of economic viability, rail transport was generally of great benefit, though in a few cases it brought a disadvantageous competition. Some examples will make this clear. In 1852, one of

the factors taken into account in a dispute between the Edinburgh, Perth and Dundee Railway and the proprietor of Cuttlehill was that without a railway for easy conveyance to the market, the coal in that property would have raised only a quarter of the rent which was actually realized⁸². Three years later, the same commentator suggested a fixed rent of £150 per annum for Lochhead minerals, but a figure of £200 to be charged in the event of a public railway being carried up to the district⁸³. Conversely, he recognised the absence of a rail link as a disadvantage at Balcaskie⁸⁴ and Mosside⁸⁵.

The influence of competition from railway-borne coal was evident in advance of railway development in Fife when in 1825, Hamilton and Geddes realised that the projected lines in the Lothians and elsewhere would lower prices to the extent that the Dunfermline product would be uncompetitive⁸⁶. The accuracy of their analysis is testified by the situation at nearby Halbeath over 25 years later, when a major factor in the 'ruinous loss' incurred by the colliery was that the carriage of coal by rail had resulted in a price reduction of fully two shillings a ton for Splint and Five Foot Coal⁸⁷. Landale, too, commented on this competition factor in recommending acceptance of an offer by the then tenant to work Kellie coals in 1854, believing that it was unlikely that some other tenant could be found⁸⁸. In the case of Kilmux, however, the fact that the colliery was altogether away from an influx of railway coal was seen as beneficial in that there was something approaching a monopoly of the local market there⁸⁹. In general, the railways served to encourage the expansion of mining in areas where the coal quality was good enough for it to find a ready sale and where there were large enough reserves to justify the investment required for large-scale production. On the

other hand, the railways served to discourage expansion on other parts of the coalfield, by bringing in good quality coal at prices with which the local pits could not compete. Thus the railways reinforced the development of mining in the West and South of Fife at the expense of the East. They also reinforced the tendency to larger, fewer collieries which then enjoyed the excellent transport facilities provided by the permanent way.

From a study of the developing railway pattern shown in figures 8.2 and 8.4, four main points emerge. First, the period between 1854 and 1912 saw an enormous growth in the rail network. The total length of track increased from about 137 Km to over 402 Km. Furthermore, this increase had taken place almost entirely in the South and West of the county - in other words, in the areas in which the coal industry was making its most rapid development. Second, the density of lines is clearly related to the distribution of the most important collieries, with only three of the pits of 1912 seeming to have had no direct railway access. One of these, the Victoria at West Wemyss, actually had a short tramway to the adjacent harbour, while the other two were comparatively unimportant. Third, it is evident that this relationship between working pits and rail transport has produced three areas of concentrated activity. The first lies in the Wemyss area, the second along the line which runs through Lochgelly and, particularly, Cowdenbeath, and the third extends along the railway line which runs North-East from Dunfermline. The fourth point to emerge from figures 8.2 and 8.4 is that the basic framework of the system was substantially in place by 1854. Here, the problem attacked was the 'strategic' one of crossing the peninsula as part of a national rail network, though ferries operated where the great Tay and Forth bridges were to arise. The framework

established, the problem of coal transport then became paramount, and this was tackled with a dense network of branch lines located in the most productive (and lucrative) mining areas of the late nineteenth century. Within the opening decade of the twentieth century, the task was complete.

A major part of that task was the carriage of coal to ports for shipment, and the developing geography of Fife's railways owes a great deal to that particular traffic. Although the three main waggonways were built to carry coal to the ports of Charlestown, Inverkeithing and St David's, the later nineteenth century saw the growing dominance of Methil and Burntisland as coal ports, so the waggonways were in varying degrees superseded as coal carriers. The kind of development which occurred may be seen in the line built by R E Wemyss from Thornton to Buckhaven and opened in 1881 at a cost of £25,000. With guarantees of mineral traffic from the colliery tenants at Leven and Muiredge, the railway was extended to Methil and a dock built there. Both railway and dock were acquired by the North British Railway in 1889, and in 1907 we see again the integration of rail and shipping facilities when a doubling of the Thornton-Leven Railway and a third dock at Methil were authorised in the same Act. As a result, the coal from the Wemyss estate came to Methil via the original Thornton-Buckhaven or 'Methil' line, while minerals from the collieries West of Thornton entered the docks from the East via the Thornton-Leven railway, the whole scheme requiring a considerable expansion of siding and storage facilities at Methil⁹⁰.

These developments were to some extent prompted by competition from the port of Burntisland, which had enjoyed the benefits of being the Southern terminus and ferry port of the line to Tayport, opened in 1847 by the Edinburgh and Northern Railway (re-styled the

Edinburgh, Perth and Dundee Railway in 1849). From the point of view of coal traffic, what was most important was the construction of a branch West from Thornton to Dunfermline and, eventually, Stirling. This served the purpose of opening up the rich coalfield areas around Lochgelly and Auchterderran, where we have seen that 'tram roads' linked collieries with the main line. An indication of the significance of rail transport is given in the 'Fife Herald' of 26 Dec 1850:

"We understand Messrs. John Henderson & Co of the Lochgelly Coal and Iron Works have been shipping from Burntisland to various parts of the Continent for some time past, between 200 and 300 tons of coal each week and, we are informed, that could more accommodation be given by the railway company, a great increase might be made to this important branch of their traffic."⁹¹

Although this implies that facilities were not everything that might be expected, the company experienced 'soaring' mineral traffic along the Dunfermline branch to Burntisland⁹². However, despite the take-over by the North British in 1862, this period saw considerable delays in the handling of coal. These seem to have got worse in the 1870s, with coal ships being held up at Burntisland as a result of the poor railway service.

In 1876 a group of coalmasters promoted a Bill to run a railway from Cowdenbeath to Burntisland, with branches to a number of collieries in the area. This would have shortened the route from more than 32 Km via Thornton to only 14, but the Bill was withdrawn with an agreement that guaranteed five years of coal traffic for the North British Company in return for better rail and harbour facilities.

By contrast, Kirkcaldy as a coal port was destined to remain in the background, mainly due to its lack of a good rail connection. The harbour had a branch line of gradient 1 in 20, so that only eight loaded waggons could use the slope at any one time. One proposal to

develop a coal port at Seafield, Kirkcaldy, was empowered by an Act of 1883. A railway was planned to run about 12 Km East from Cowdenbeath to Seafield, but although the line was indeed completed in 1896, it was by then under the control of the North British, who arranged the junctions to facilitate access to the Burntisland docks. The harbour project was abandoned.

In considering rail transport, we have looked at its role in colliery viability, how the network developed in servicing the coal trade, and we have noted how the rail pattern was related to the shipment of coal from the harbours of Fife. The significance of this third aspect will become clearer as we proceed to examine the development of coal shipment in Fife, a trade which was of crucial importance for the rise of the mining industry.

Shipment

In the sixteenth century the use of coal as a fuel was becoming widespread in Scotland, and due to the inability of producers to keep pace with demand, Acts were passed prohibiting its export, but were unsuccessful in restricting the rapid rise in the foreign coal trade. In the seventeenth century, an export duty was substituted for the prohibition but by the later years of that century the coal trade had further expanded. Although the busy exporting collieries of Culross, Dysart and Wemyss saw considerable development at this time, the trade with the wealthy Dutch market was carried on from a large number of small harbours right along the North shores of the Forth. At Kincardine, for example, 1679 saw an output of some 15,000 tons (15,240 tonnes) per annum, most of which must have been exported due to the fact that roughly as many people were employed in loading ships as worked in the mines⁹³. At the Eastern end of the county, we find

customs records of coal exports from Crail, Anstruther, St Monance and Pittenweem, the last of which Nef ranks as among the area's principal coal exporting ports at the time of the Civil War.

By the middle of the eighteenth century, the picture was still substantially one in which a number of small harbours shipped coal, both coastwise to centres of population and overseas to the Low Countries and the Baltic. A good example is found in Kirkcaldy, where in mid-century the Rothés estate had access to the port by renting a coal yard there. An account for July, 1749 shows that nearly 150 tons (152 tonnes) of Rothés coal were sent to Kirkcaldy during that month, which must have been a major portion of the output⁹⁴. From Kirkcaldy the coal was shipped mainly to Leith or London, but some also went to Holland, where Fife coal remained in high demand. Indeed, the quantity of coal exported grew considerably in the second half of the eighteenth century, with the Kirkcaldy total for the three years 1744-6 being only 4746 tons (4822 tonnes), compared with 12,573 tons (12,774 tonnes) in 1764-6 and 22,577 tons (22,938 tonnes) in 1784-6⁹⁵. A similar growth in coastwise shipments was achieved despite a heavy burden of tax, but by the end of the century, the duty on coals carried beyond the mouth of the Forth had been abolished and there was a need to develop domestic markets brought about by the trade dislocation resulting from the war against France. In the 1790s the typical coal harbours of Dysart, Wemyss and Methil shipped 54% of their total overseas and 46% coastwise⁹⁶. More specifically, the colliery at Dysart enjoyed a landsale of some 7,000 tons (7112 tonnes), a coastwise shipment of 3583 tons (3640 tonnes) and an export of 4584 tons (4657 tonnes), this last chiefly to Copenhagen, Gottenburg and Holland⁹⁷.

Associated with the eighteenth-century growth in shipment were harbours developed as outlets for waggonway coal from inland pits, and also harbours developed for the shipment of coal from collieries in the immediate neighbourhood. The former includes Charlestown, Inverkeithing and St David's, while a good example of the latter is to be found at Pittenweem. In 1771 Sir John Anstruther entered into an agreement with the town of Pittenweem to form a basin at the harbour, erect new quays and to rebuild part of the old pier in return for certain privileges in the shipment of coal and salt⁹⁸.

In the first half of the nineteenth century, further developments in Fife harbours continued to be associated with the shipment of coal, but the growth in the coal trade was not such as to stimulate much activity. In fact, the trade languished for a time and it was not until about 1830 that some revival was able to justify harbour improvements. For instance, in that year Charlestown harbour was reconstructed, the pier being extended and a sluicing canal dug from the Lyne Burn. An old quarry was used to store the water till low tide when it was released to wash silt out of the harbour⁹⁹. The effect of this reconstruction on the coal trade is evident from figure 8.5, despite the seasonal fluctuations. In 1831 the first wet dock in the county was built at Dysart, where it had originally been an old quarry adjoining the harbour¹⁰⁰, and St David's was also greatly enlarged, first in 1826 when the harbour was deepened and again in 1832 when the South pier was extended by 46 metres¹⁰¹.

The period from about 1850 to 1914 witnessed an enormous growth in overseas sales, stimulated mainly by the fast pace of industrialisation abroad, and the Fife coalfield was well placed to meet this demand. What it meant for harbour development, however, was that traffic

became concentrated in the ports capable of handling large-scale shipments. Good rail connections with inland collieries were essential, and the ports which came to dominate Fife's shipment were Methil, Burntisland and, to a lesser extent, Dysart, Wemyss and Charlestown (see fig 8.6). These five ports shipped no less than 49.4% of Fife's output between 1895 and 1900, compared with about 18.9% of Scotland's output being exported and 17.8% for the UK¹⁰². A brief look at each of the five will illustrate how the development of these harbours has been related to progress in the mining industry.

David, Earl of Wemyss built the first stone harbour at Methil in 1664, the first vessel to enter being to collect a cargo of coal for shipment to Leith. By the time of the Old Statistical Account Methil was connected with the pits by a two-mile long waggonway, and according to the Minister 'everything promises an extensive trade..... it would not be at all surprising to see, in a few years, Methil rank among the first coal-ports in Scotland'¹⁰³. Although these words were indeed prophetic, it was not until the second half of the nineteenth century that Gib's prediction was to be fulfilled. In the meantime, shipments remained small-scale. By 1838, despite there being a very extensive coalwork in the parish employing over 200 people, the harbour at Methil rates little more than a mention in the New Statistical Account of that year¹⁰⁴. Eight years later, in an interesting piece of minor evidence, we find Methil comparing unfavourably with Wemyss in a shipping report of 1846. In the week ending 14 March of that year, Methil shipped only 127 tons (129 tonnes) in three vessels, while Wemyss shipped 661½ tons (672 tonnes) in no fewer than 11 vessels¹⁰⁵.

During the 1860s and 70s, the expanding East Fife coalfield led to the realisation that Methil could be an ideal outlet, and in 1881

the railway line built from Thornton to Buckhaven was extended to Methil. A new dock was opened at the port in 1887, including three hydraulic coal hoists and electric lighting, and the dock and railway were bought by the North British Company in 1889. The facilities soon proved inadequate for the growing coal traffic and a second dock was completed in January, 1900, a third following in 1913 (see fig 8.7). Although a glance at fig 8.6 shows how Methil and Burntisland together came to dominate Fife's other coal ports, Methil's significance for the county as a whole may be illustrated by the fact that in 1837, Methil shipments were only 8.5% of Fife's total coal output, while in 1904, they were over 30% of the total, amounting to nearly two million tons (2.03 m. tonnes)¹⁰⁶.

Fife's other great coal port, Burntisland, was originally of much greater importance than Methil. Already a principal port of the Firth of Forth by the mid sixteenth century, the town maintained this position after the coming of the railways by being the Northern terminus of the important ferry to Granton. However, delays in coal shipment were the subject of widespread dissatisfaction about 1870, and in August 1872, no fewer than 50 coal vessels sailed from Burntisland harbour, mainly for the Baltic. The following month, 62 vessels were reported lying in the harbour, some having waited several weeks for coal. A new wet dock was opened in 1876, including the introduction of three hydraulic coal hoists, the first of their kind in Scotland. There was no attempt to provide for a general shipping trade, the export of coal being the principal aim:

"It seems to be the general opinion that the present dock is only sufficient for coal shipping, and that any attempt to accommodate a general trade will act prejudicially to the dock revenues, by hampering the coal shipments."¹⁰⁷

The introduction of a direct rail link with the West Fife coalfield and

Forth Bridge meant that the now superfluous ferry harbour could be converted to cope with the increased coal trade, and a new harbour and dock area was opened in 1901 (see fig 8.8). The resulting increase in coal shipment may be gauged from fig 8.6 and actually amounted to a rise of nearly 55%. Despite this, Burntisland failed to regain its dominance over Methil although it successfully arrested its decline relative to that port. This was partly due to a decision by the North British Company, who controlled both ports following the Burntisland Harbour Act of 1896, to concentrate further expansion at Methil.

The seventeenth century importance of Dysart is illustrated by the fact that about 1640, when part of the pier needed repairs, collections of money were made throughout the Presbytery of Dunfermline as well as in several other Fife locations¹⁰⁸. We have already noted the shipment of coal at the time of the Old Statistical Account and referred to the new dock of 1831, but there were subsequently no major developments at Dysart. Despite attempts to build up Kirkcaldy in the 1880s, that port enjoyed a moderate success only with other cargoes, and Dysart continued as the more important coal harbour of the two. At Wemyss, a dock of 1873 was destroyed in a storm in 1898, but was reconstructed and coal shipments were resumed at a rate of up to 60,000 tons (60,960 tonnes) per annum. As with Dysart, West Wemyss failed to compete with the bulk facilities at Burntisland and Methil but served well enough for the shipment of coal from the nearby pits of the Wemyss Coal Company. Charlestown harbour, built in 1778 for the trade in coal, salt and lime, came to be dominated in the nineteenth century by the first of these, particularly following its reconstruction of 1830. Taken over by the North British Railway Company in 1862, it became an outlet for much of the coalfield area around Dunfermline by virtue of the good rail link provided by the

Elgin Railway. In 1863 the harbour was extended and improved but steadily lost traffic to the better facilities at Burntisland, despite the Company giving a uniform rate to both ports.

In general, we may identify a relationship between the coal industry and Fife's harbour developments in which the shipment from virtually every Forth harbour in the seventeenth and eighteenth centuries became radically unbalanced in the late nineteenth century. At that time, the explosive development of Methil and the slower but still remarkable expansion of Burntisland meant that these two ports took full advantage of their excellent rail links with the rich inland coal-producing areas to build up a powerful trade. The importance of the rail link is emphasised in two ways. First, both ports were for much of their ascendant period in the control of the North British Railway Company. Second, the ports which best survived the competition, namely Charlestown, Dysart and West Wemyss, were either well supplied with rail links of their own (Charlestown) or fed their shipping trade from collieries within easy reach of the harbour (Dysart and West Wemyss).

Coal Markets in Fife

Despite such a massive reliance on shipment throughout its history, the Fife coalfield was also subject to influences from both the household and local industrial markets. Coal was a popular household fuel in Fife at an earlier period than in the rest of Britain, perhaps encouraged by its use in the Falkland Household of James VI. By the early eighteenth century household consumption accounted for about two-thirds of the UK coal output, about a half in 1800 and by 1873, the household market took only one-sixth of Britain's output, despite a doubling of the per capita consumption in the 40

years up to that date¹⁰⁹. Thus during the eighteenth and nineteenth centuries household consumption expanded in absolute tonnage while declining in importance relative to other markets. Bald summarised the state of affairs in 1808 when he attributed the increased coal consumption first to the style of living, in which a person kept at least double the number of fires in his house compared with 50 years previously, second to the extension of the iron trade and other manufacturing, and third to the burning of lime which went mainly for agricultural purposes¹¹⁰.

The increasing share taken by industrial markets brought considerable benefit to the Fife coal industry in that demand became less seasonal, a feature already noticed in the shipping figures for Charlestown. In 1777 James Pinkerton wrote of St David's:

"We have this year built a steath at St David's which may contain 5 or 6 thousand carts of coal - there are three months in the spring in which the London market is very dull and any person freighting ships in these three months must frequently be brought in for large sums of Demurrage besides the loss attending low prices - Our plan therefore is to let all the Scots ships load at Bo'nese on their own accounts during these months, and to lay our own coals in the Steath. And in the month of June when the demand increases in London to freight so many English vessels as will take away what coals there may be at both works, more than the Scots vessels carry off."¹¹¹

and in 1848 Cadell was referring to an indirect use of coal mainly in towns and cities when he commented on stocks held at Methil:

"There are at present 34 men in the pit and were these reduced to 20 and kept on two-thirds output I have no doubt the stock will gradually decrease, more especially as this is about the time when the gas works begin to lay in their stocks so that for some months to come a considerable increase in the shipment may with confidence be anticipated."¹¹²

About the same time, Henrietta Keddie's father was disadvantaged by a lack of labour at Grange, where many of the men went off to the herring

fishing at the very time of year when the colliery ought to have been building up stocks of coal in anticipation of the winter's demand. In this case the wages saved were more than offset by the inability to lay up a sufficient stock of coal for the winter¹¹³.

The strategies which were adopted to cope with the seasonal nature of the demand for household coal were not required for the supply of industrial markets, where the demand was generally more steady. Partly because of this steady demand, the development of the Fife coalfield was significantly interwoven with the local coal-using industries. Although the manufacture of bricks, brewing and distilling were occasionally of some importance it is in the fields of salt, lime and iron manufacture that we find industries of more general influence.

First, although the salt industry fell into decline after 1825, it is clear that the demand created by Fife's many saltpans had already encouraged the exploitation in the seventeenth and eighteenth centuries of the coastal seams where the day-level drainage technique could be readily applied (see fig 8.9). The influence of the saltpan market was also felt at inland collieries with the building of the eighteenth century waggonways. Elgin, Halbeath, Fordel and Wemyss waggonways all terminated at harbours which incorporated sizable saltworks, and coal was sent to the coast for both shipment and salt manufacture. This association of two markets was particularly convenient due to the fact that shipments were mainly of 'Great coal' while saltpans consumed small coal, known disparagingly as 'panwood'. It may be estimated that about one-seventh of Fife's total output in the 1790s was consumed in the county's saltpans¹¹⁴.

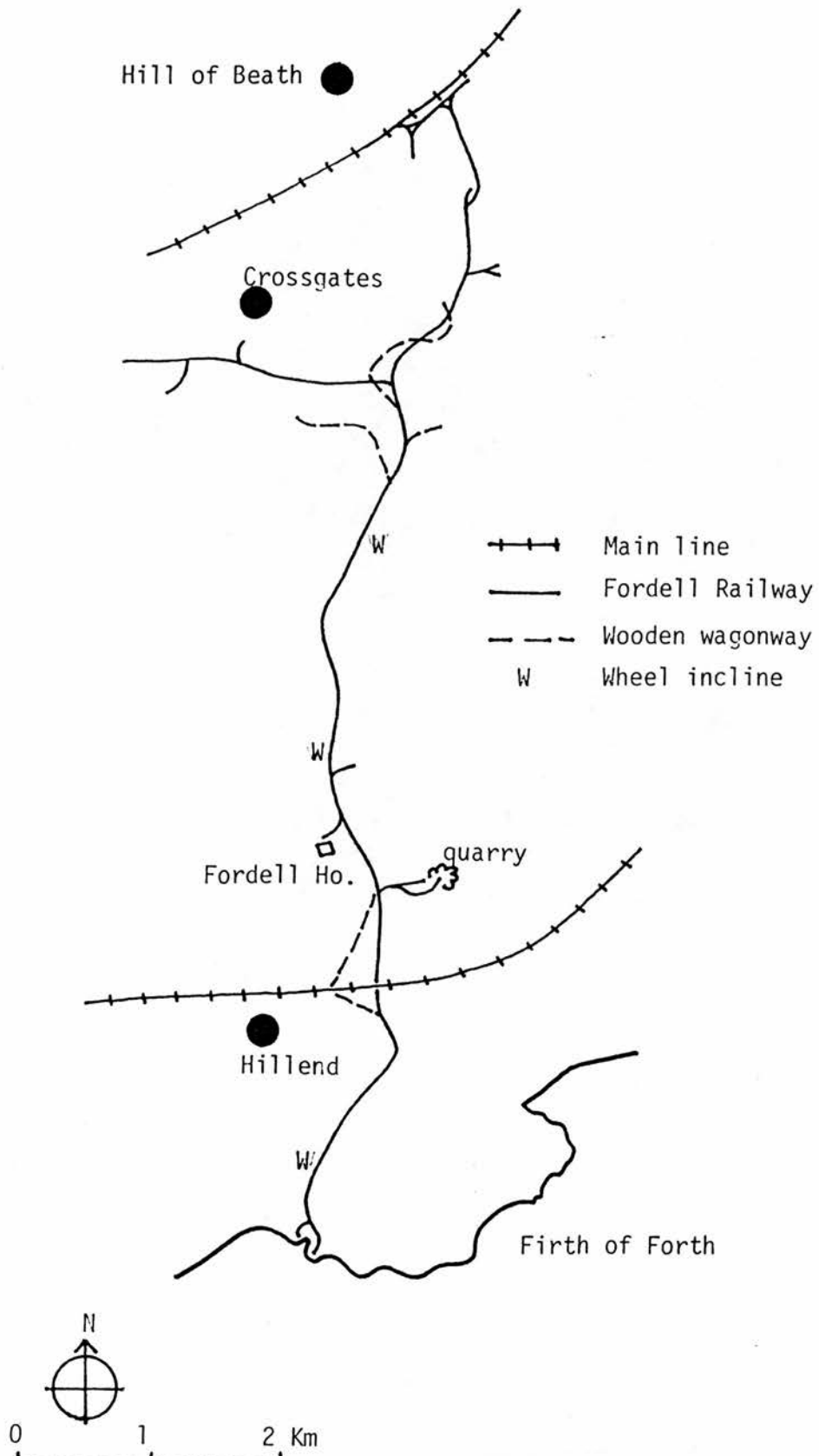
The demand for lime was stimulated by agricultural improvements, the building industry and the manufacture of iron. It was of a widespread nature and encouraged the more scattered, often small-scale, development of mining throughout the coalfield, partly due to the distribution of agricultural land in Fife (see fig 8.10). Coal consumption varied too much for any reasonably accurate total to be calculated for Fife, and kiln improvements are known to have reduced the amount of coal used in each firing, but we can quote the case of the uniquely large enterprise at Charlestown, where the 1840s saw the consumption of some 20,000 tons (20,320 tonnes) of coal per annum. This represented about one-third of the output from the Elgin collieries, the remainder being shipped. Fortunately, the limekilns were similar to saltpans in that they provided an outlet for poor quality coal difficult to sell elsewhere, and the term 'limecoal' soon came to denote inferior fuel, as had 'panwood' a hundred years before.

By the mid nineteenth century a third industrial coal market had arisen in Fife, and in this case the effects were more localised (see fig 8.11). Although an iron works had existed at Balgonie between 1801 and 1815, the major development took place in mid-century and depended on the occurrence of Blackband Ironstone rather than on the supply of coal, which in Fife was of poor coking quality. Nevertheless, by the 1850s there was a considerable amount of iron mining going on in Fife and blast furnaces were to be found at Lochgelly (1847-75), Lumphinnans (1850-74) and Oakley (1846-69). However, of 13 furnaces in 1869 only four were then in blast, so the industry could not have provided the coal market which general figures for blast-furnace consumption would at first suggest. At their peak,

the furnaces are unlikely to have consumed much more than 50,000 tons (50,800 tonnes) per annum and this on a coalfield with an output of 1.25 million tons (1.27 m. tonnes) per annum by 1870. Despite this, the widespread appearance of iron mining evident in fig. 8.11 and the significance of the furnaces for their local pits cannot be ignored. For example, the Tom pit is known to have sent 20-25,000 tons (25,400 tonnes) per annum to the works at Oakley, and at Lumphinnans the furnaces took 53.5% of the disposals from Lumphinnans colliery between 1860 and 1874¹¹⁵.

In summary, we have seen that the increasing growth of coal transport in Fife has been subject to the requirements of the main markets for coal, particularly shipment, which resulted in the development of the Forth harbours and the railway lines which linked them with the producing collieries. The county's industrial coal markets also influenced the evolution of the mining industry but were themselves the result of local resources exploitable only with the aid of cheap fuel. Between 1750 and 1914, practically every great industrial or commercial enterprise in Fife was intended to foster, or was a consequence of, the rise of the coal industry, itself subject to the opportunities and limitations provided by its own changing technology.

Figure 8.1 THE FORDELL RAILWAY



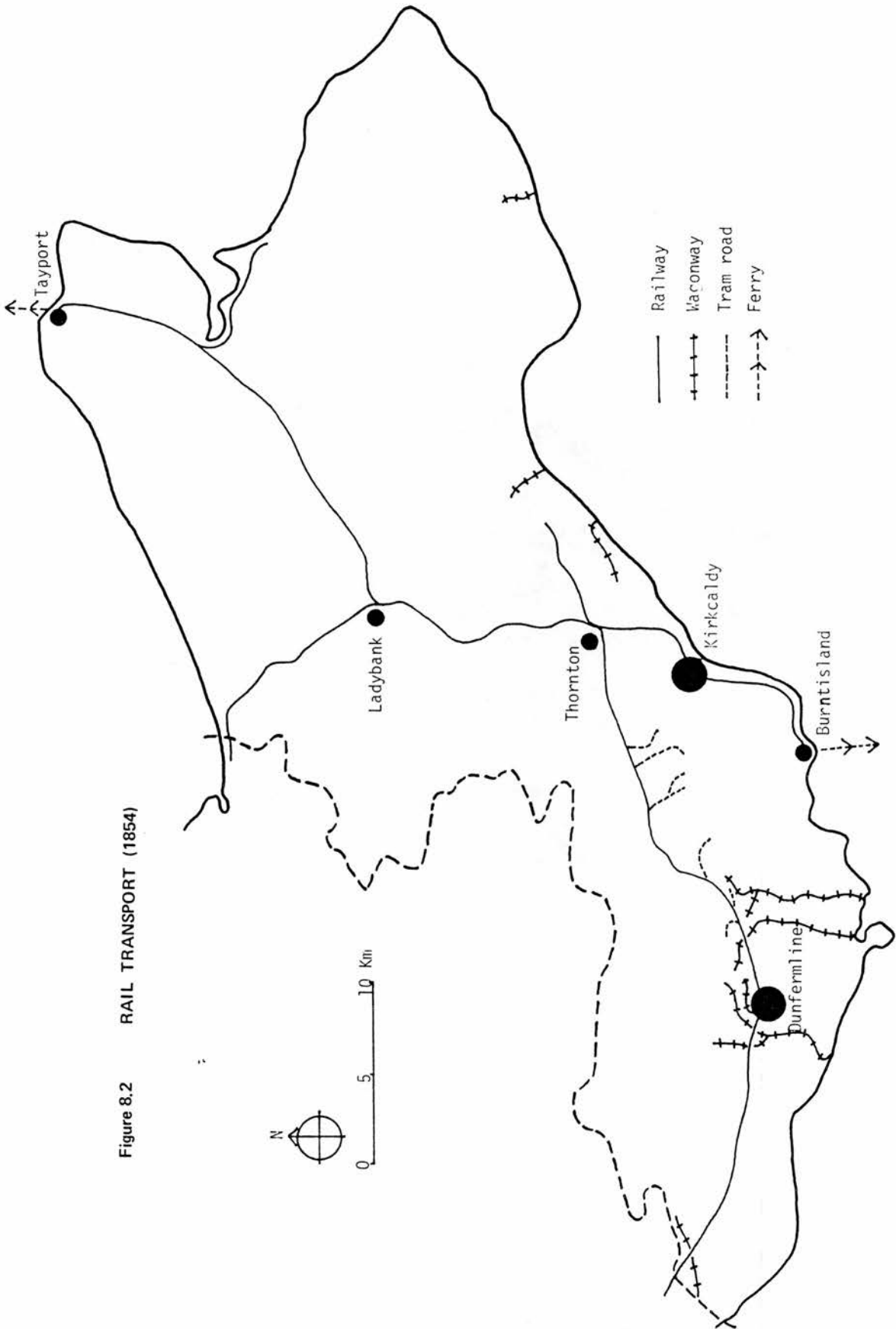


Figure 8.2 RAIL TRANSPORT (1854)

Figure 8.3

INCLINED PLANE WHEELHOUSE AT VANTAGE, FORDELL (1838)

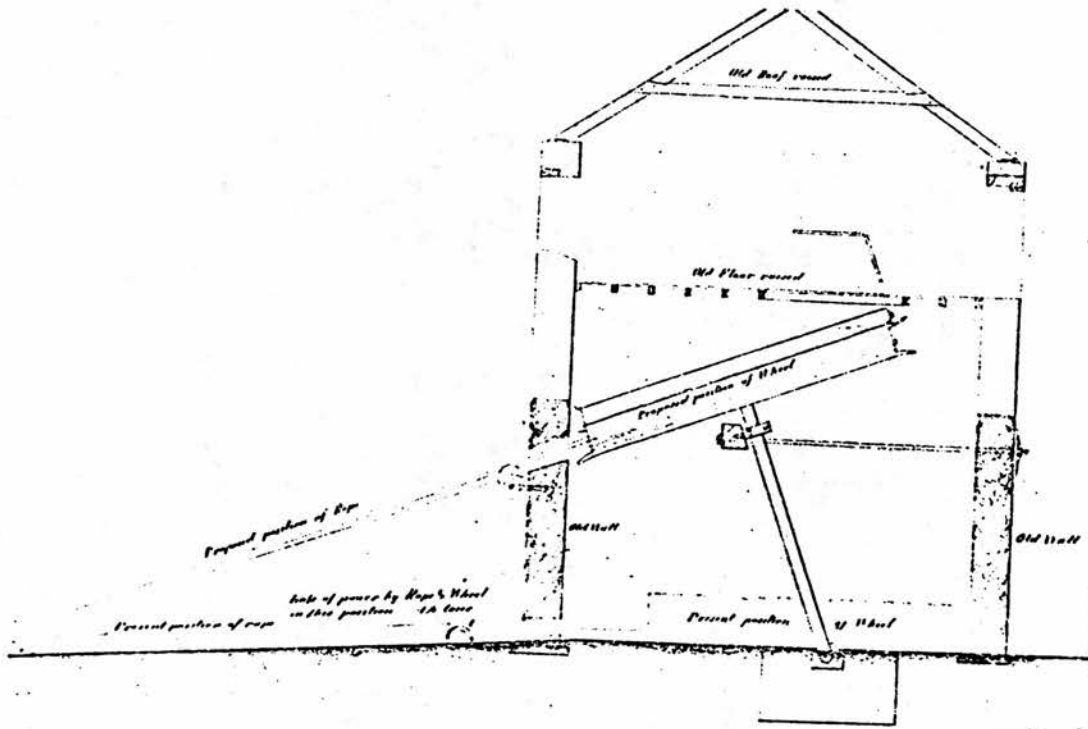


Figure 8.4 RAIL NETWORK AND MAJOR COLLIERIES (1912)

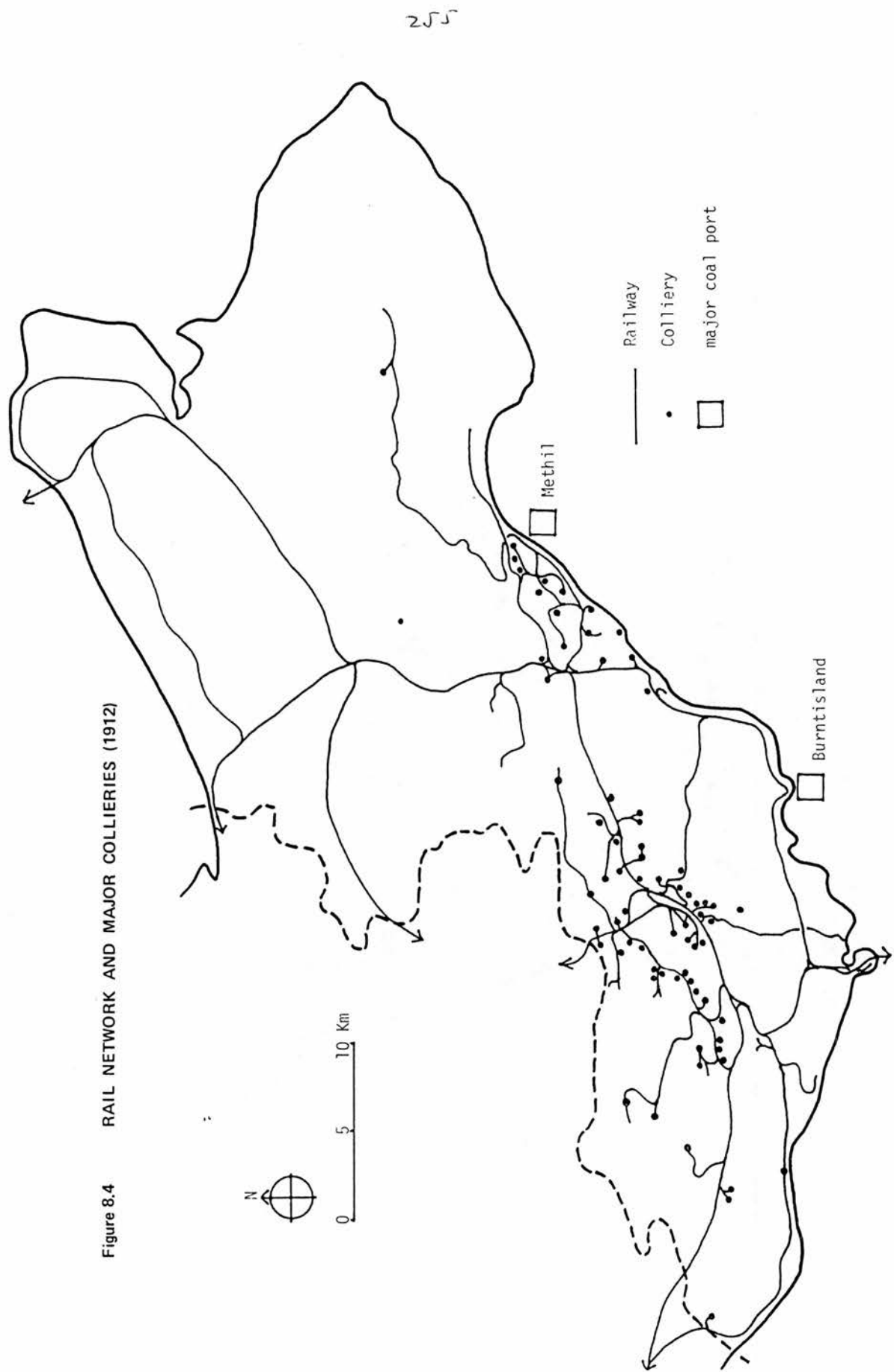
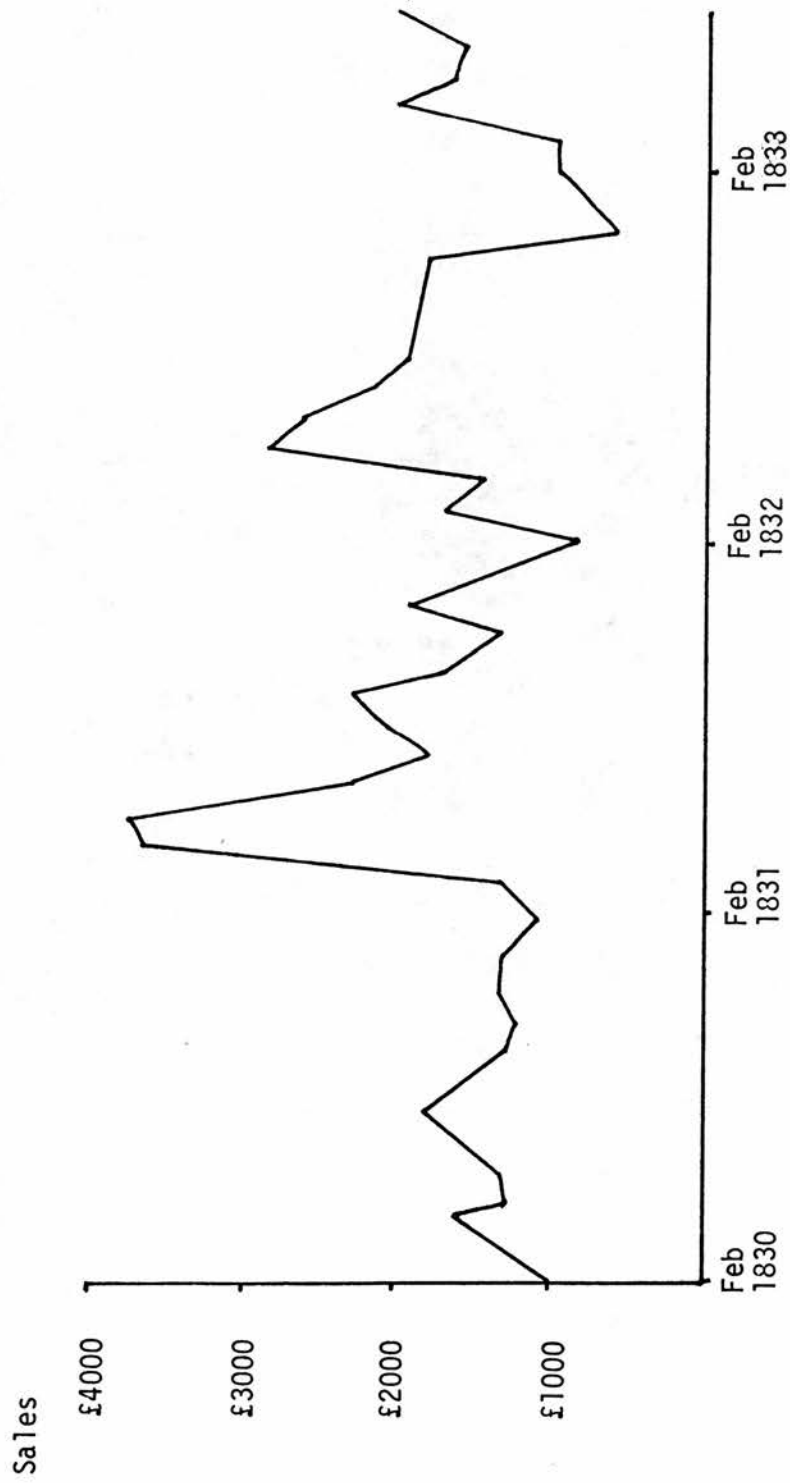


Figure 8.5 CHARLESTOWN COAL SALES (FEB. 1830-JULY 1833)



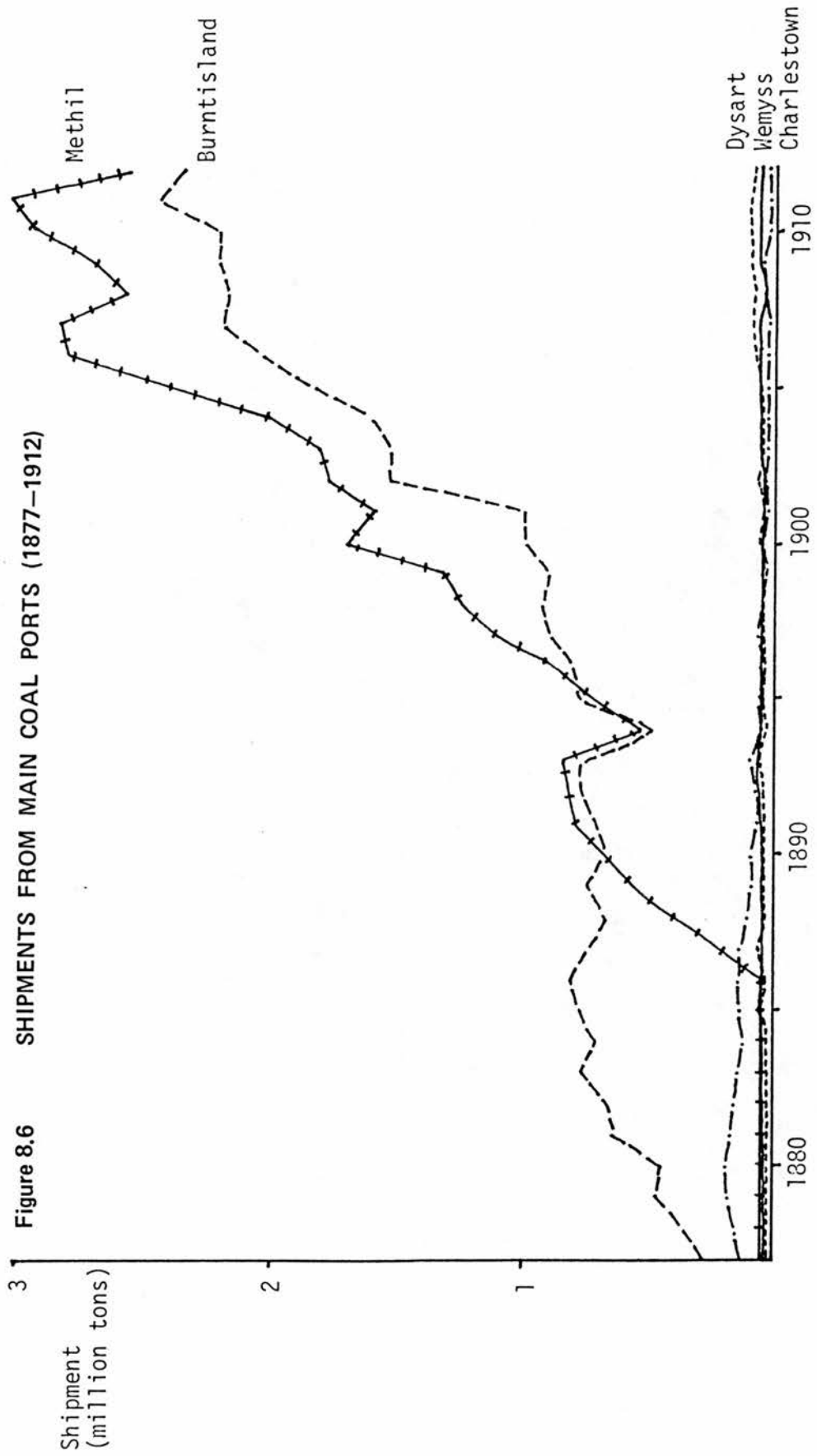


Figure 8.7 METHIL DOCKS (1914)

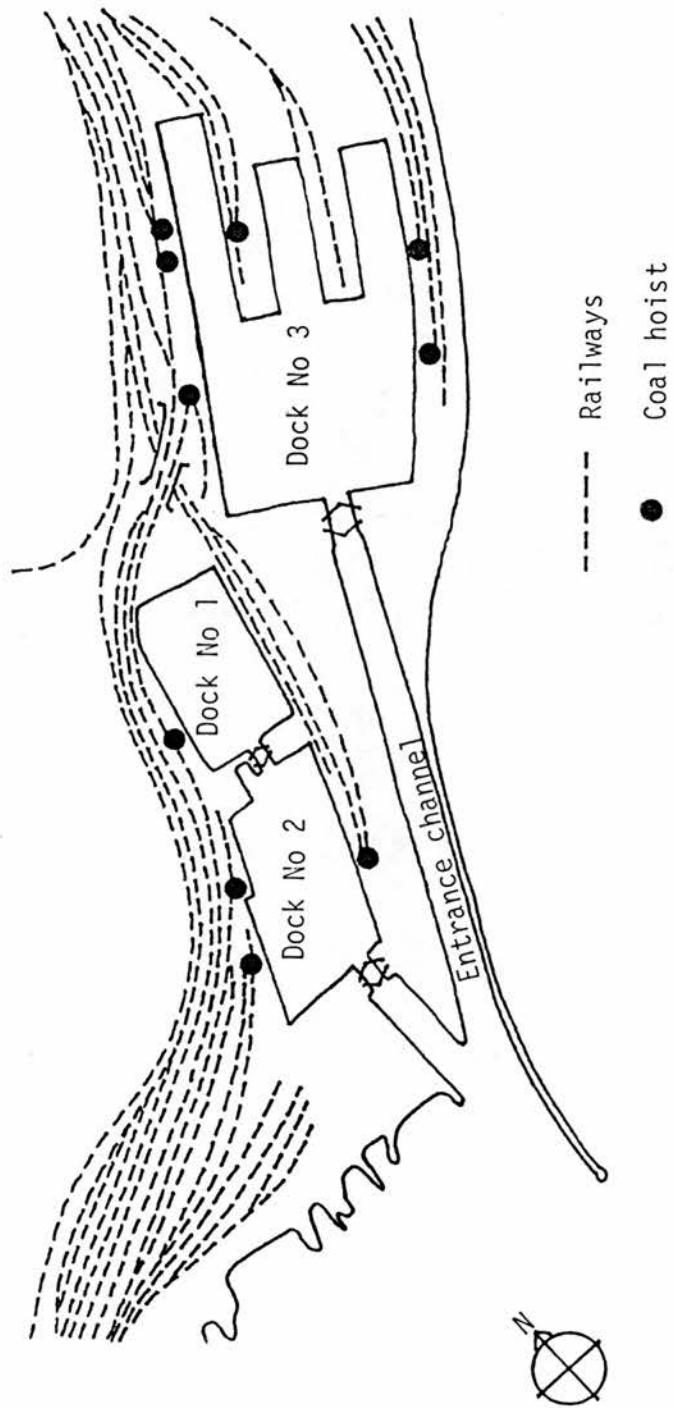


Figure 8.8 BURNTISLAND DOCKS (1914)

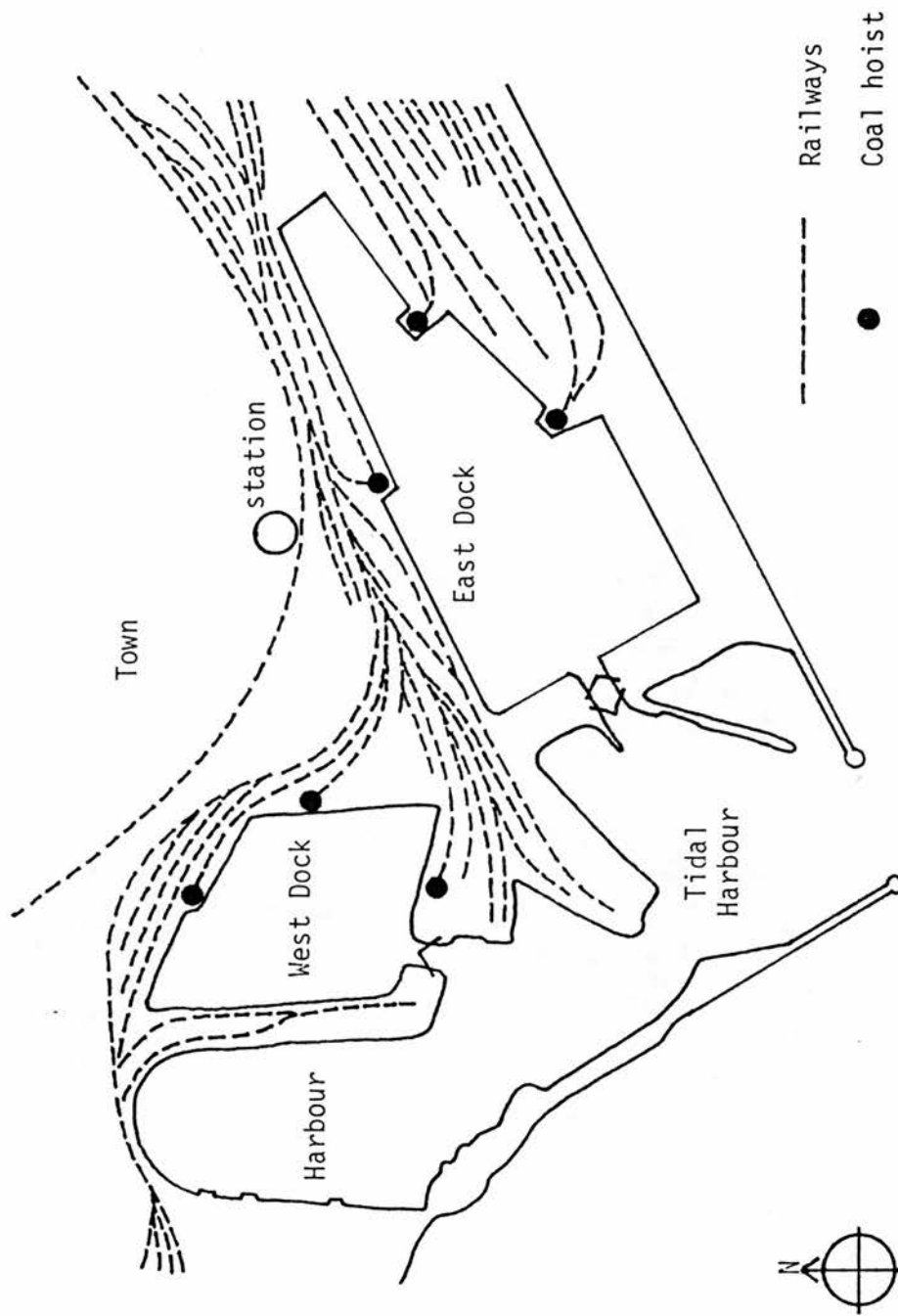
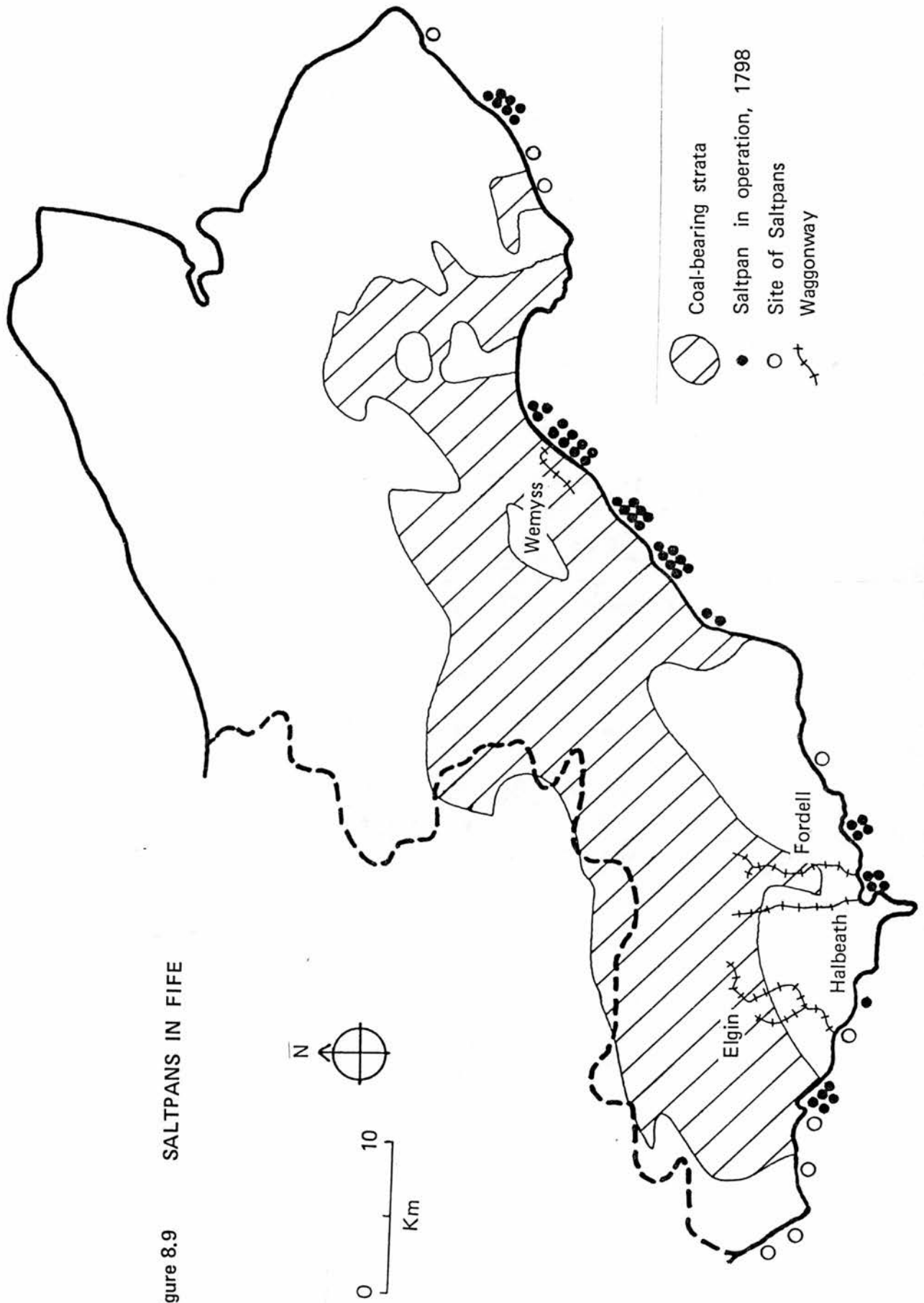


Figure 8.9 SALTPANS IN FIFE



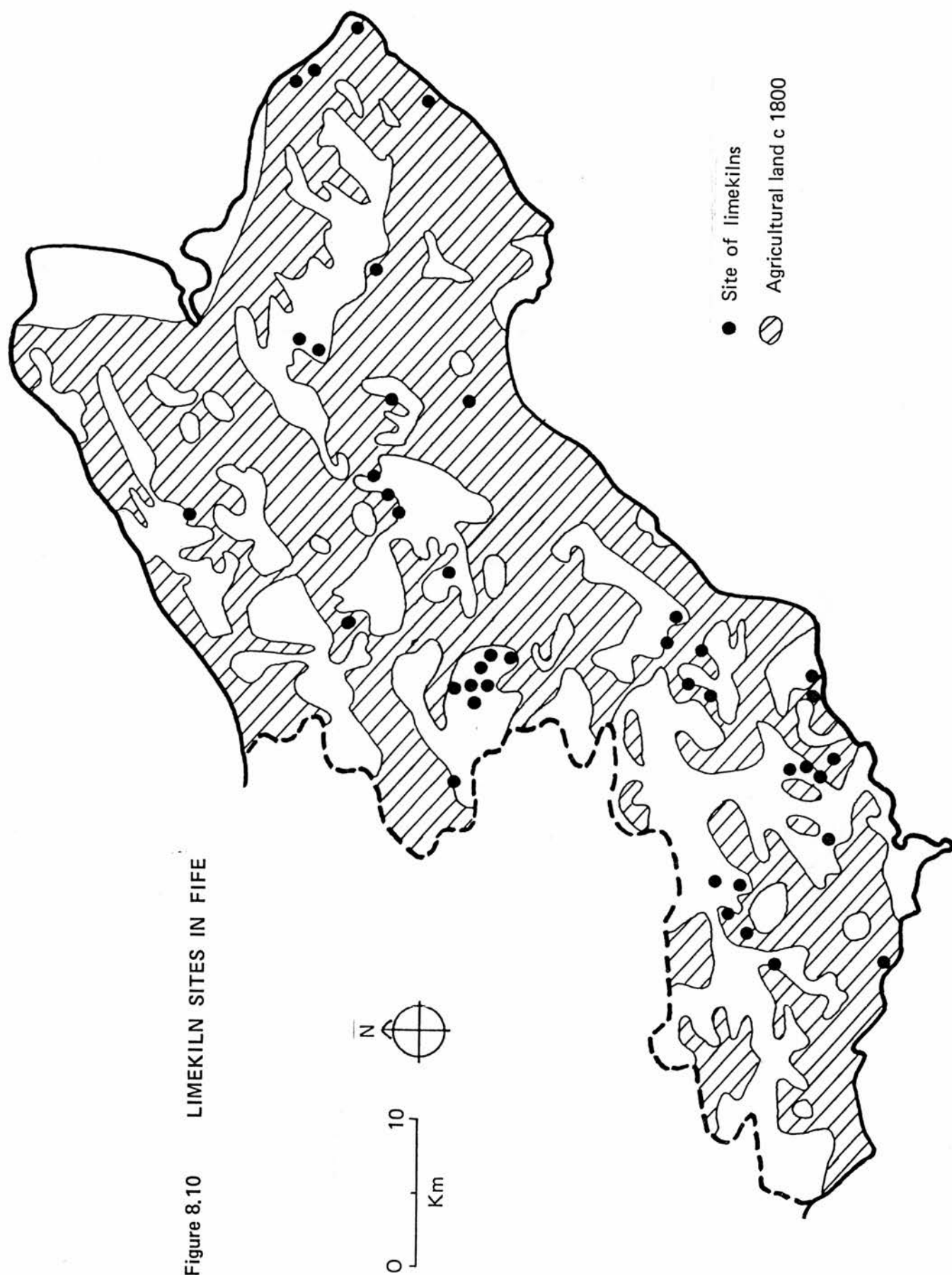
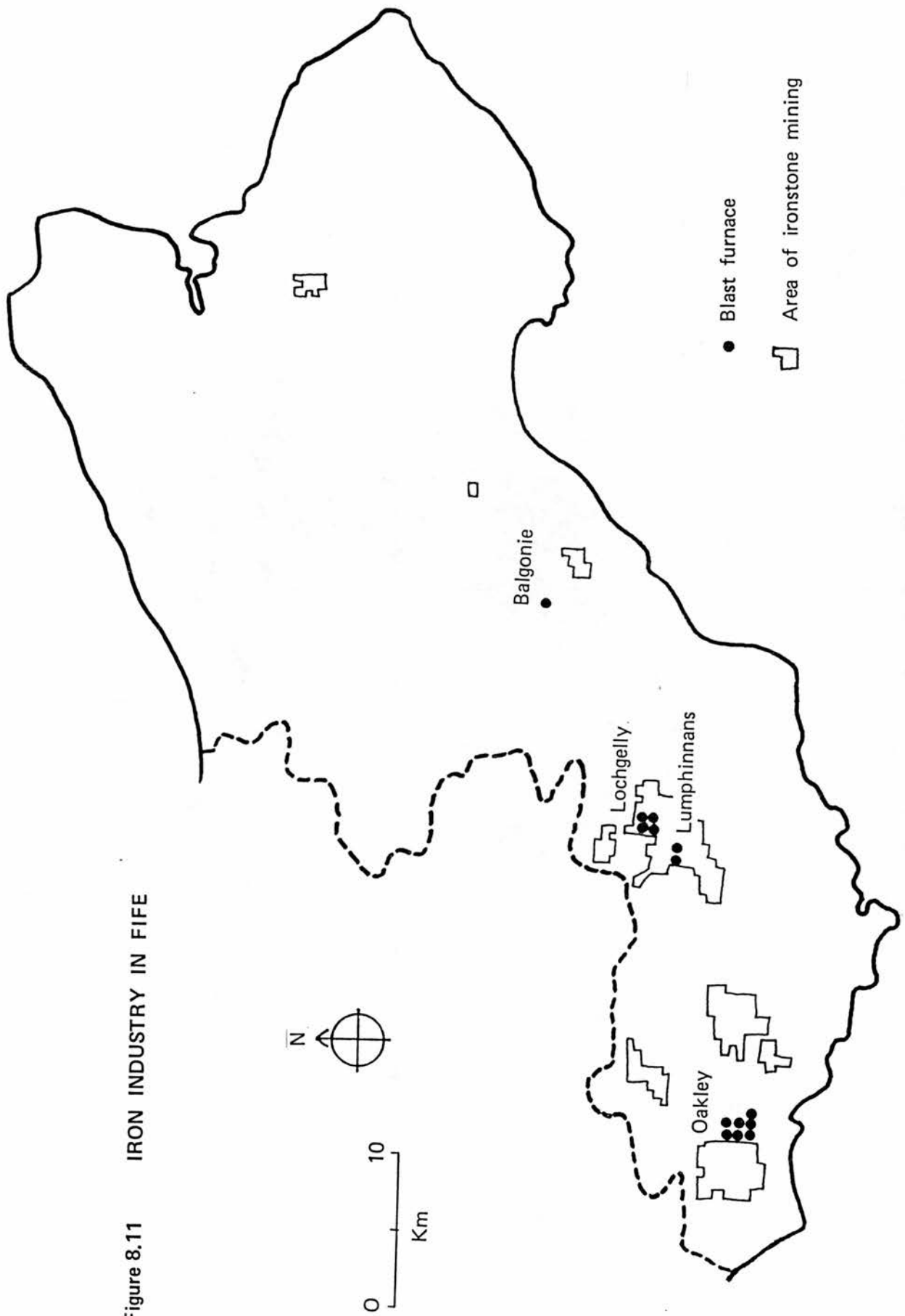


Figure 8.11 IRON INDUSTRY IN FIFE



CHAPTER 9 - POPULATION

Population change is probably the single most significant index of Regional Development, since it is intimately associated with economic advance, and reflects both the quantity and quality of change. Our discussion will attempt to explore the relationships between changes in the size and distribution of Fife's population on the one hand, and development of the Coal Industry on the other. The first task in such an exploration is to identify the main characteristics of Fife's changing population in the period 1750-1914. There are three.

The first characteristic is one of growth, particularly during the last half century of our period. A special feature of this was explosive growth in a few parishes, and we shall see that the Coal Industry played an important part in this development.

Arising from this special feature comes the second characteristic. The period saw a significant shift in the distribution of Fife's population from a fairly even spread in 1755 to a distribution in 1911 in which there was a marked concentration in the South and West of the county. There was also an increasing contrast between parishes with a growing population and those where population had remained static or declined. We shall see that this shifting distribution of population in Fife owes much to changing levels of coal-mining activity.

Thirdly, the period 1750-1914 saw a move from rural areas into the towns of Fife. Unfortunately, this shift can only be accurately determined from mid nineteenth-century when the census first recorded Burgh populations separately, but we shall consider how far this change can be explained by the Coal Industry and will see that in

some areas it is a factor of considerable significance.

Characteristic 1: Population Growth

Fife's population growth 1755-1911 is shown in figure 9.1. The figure from 1755 is that from Dr Webster's Census¹ and that for 1791 from the Old Statistical Account. Later figures are from the Registrar-General's decennial Census, begun in 1801.

It is clear that growth, though continuous, has not been at a constant rate, and it is possible to identify five main stages using the information in the figure and Table 9.1. The first phase, that from 1755 to 1791, was a period of slow but steady increase, with an average decennial increment of 1570. The next two decades saw an increased rate of growth, with decennial increases of 6519 (1791-1801) and 7529 (1801-1811). This period was succeeded by phase three, where decennial increases were over 10,000 for four decades. In 1851-1861, however, the growth pattern was seriously moderated, with an increase of only 1224, a figure reminiscent of the late eighteenth century. The fifth and last phase commenced in 1861, with a steadily increasing growth rate culminating in the enormous increase of 48,896 in the 10 years 1901-1911.

These five phases differ from Stephen's analysis in two main respects. First, he identifies no "break" after 1791, whereas for present purposes it is considered that a change from a mean decennial increase of 1570 to 6519 and 7529 is a significant one. Second, Stephen emphasises 1881 as 'a turning point' after which Fife's population decline relative to the rest of Scotland was reversed². This is probably of significance here only in that it reflects the massive growth in Fife's population towards the end of the nineteenth century - a growth which might be substantially explained by a

burgeoning Coal Industry in the County at that time.

The role of the Coal Industry in explaining this pattern of population growth can be examined by comparing population change in "coal mining" parishes with change in "non coal mining" parishes. This goes at least part of the way towards isolating the 'coal factor' in Fife's demographic history. In this study Fife's 60 modern parishes have been adopted as standard, with boundary changes being taken into account in compiling statistics. Thus any references to parishes by name are to the modern unit of that title.

In order to achieve an objective classification of the 60 parishes into 'coal' and 'non coal', it was decided to adopt a purely physical criterion which could introduce no unnecessary bias into the population patterns of the two types. Clearly, a 'coal' parish, defined as 'a parish within which a significant amount of coal mining activity had at some time taken place', would exhibit physical evidence of mining in the form of abandoned workings. These are recorded in the 'Catalogue of Plans of Abandoned Mines', and it was decided that the number of entries per parish provided a convenient and objective criterion with which to measure the 'coalness' of a parish³. The number of entries per parish was added up and the results are shown in Table 9.2. The question then arises as to what is meant by a 'significant' level of mining activity. It might be argued, for instance, that one entry in the Catalogue is hardly enough to justify classifying an entire parish as 'coal' when its character might be in every other way overwhelmingly typical of the 'non coal' group. Careful inspection suggested that five entries in the Catalogue seemed a reasonable cut-off point with which to classify parishes. However, this process had the disadvantage of introducing a somewhat

arbitrary element into the classification procedure, so it was decided that a second criterion would be required in independent confirmation of the Catalogue results.

Since the point at issue here is how far the Coal Industry influenced the growth and distribution of Fife's population, it was decided that the number of coal miners per parish in a sample census year would be an appropriate second criterion. Although this might be unsatisfactory if used to perform the classification on its own (since a parish with a large number of miners would naturally show a distinct coal influence in its population growth pattern), it is used here only to test the validity of a much more objective measure and it is felt to be a permissible exercise. The year chosen was 1861, partly because information was readily available from census enumeration books and partly because it was the latest nineteenth-century census with a total number of miners still manageable at 3801. Since the identification of occupations may be unreliable, only individuals identified as 'Coal Miner' or 'Collier' were counted. This method produced a figure about 1,000 less than that published in the Census Report for that year.

Table 9.2 gives the results of this enumeration, and there is a very clear correspondence between the number of entries in the Catalogue and the number of Coal Miners/Colliers found in 1861. This suggests that Catalogue entries are indeed a valid measure of 'coaliness'. It suggests, too, that the adopted cut-off of five entries is appropriate. There are seven parishes with entries numbering between one and five. (Anstruther Wester, Burntisland, Elie, Kennoway, Kinghorn, St Andrews and St Leonards, St Monance). In five of these, there were no miners at all in 1861 (Anstruther Wester, Burntisland, Elie, Kinghorn, St Monance) and in the other two

parishes (Kennoway, St Andrews and St Leonards) the miners total only 7 in each case.

On these grounds it was decided that any parish with five or more entries in the Catalogue would be classified as a 'coal' parish, and the others as 'non coal'. This produced a total of 25 'coal' parishes and 35 'non coal' parishes (see Table 9.2). Given that this classification of parishes is a reasonable one, it remains to discover if the two groups show differences in their patterns of population growth - differences which in all probability are due to the 'coal factor'.

Mean figures were calculated for each of the two types of parish and the results are shown in figure 9.2. Several points of interest emerge. The first is that the differences between the two sets of data are statistically significant, since there is no overlap at all between them. The lowest population of the mean 'coal' parish (1880 in 1755) is still higher than the peak of the 'non coal' parish (1873 in 1881), and the gap between the lines becomes more pronounced as the nineteenth century proceeds. In 1755, for instance, a difference of 823 is found. By 1801 this had increased slightly to 1063, but by 1851 had nearly doubled to 2091, a position which makes the average 'coal' parish at that time more than twice as populous as the equivalent 'non coal' unit. The gap increased dramatically in the later part of the nineteenth century and by 1911 the mean 'coal' parish had a population of 8130 compared with only 1842 for the 'non coal' parish, a ratio of 4.5/1.

This increasing gap reflects the fact that throughout the period, growth in coal mining areas was greater than in areas with little or no coal mining. Even in the late Eighteenth Century, when the scale of mining over much of Fife was still comparatively

small and mining employment limited in comparison with textiles and agriculture, the population graph rises more steeply for the average 'coal' parish than for the 'non coal'. This difference in growth rate is accentuated in the first half of the Nineteenth Century, but is made even more remarkable in the next 50 years with an actual decline (albeit slight) in 'non coal' population while the 'coal' areas experienced their exponential increase.

It is interesting to note here that Fife's total slowdown in growth 1851-1861 actually represents a rise in 'coal' areas counteracting a slight decline in 'non coal' parishes.

While every attempt has been made to use only the 'coal factor' in classifying parishes into these two groups, it may be that other influences come into play. For instance, since 'coal' parishes will be distributed within the County according to the location of coal-bearing strata, it may be that it is their location rather than their 'coalness' which is the principal determining factor in population change. However, the comparatively even spread of population in 1755 would imply that this is unlikely, and the fact that significant differences emerge in two sets of data classified solely on the basis of the relative abundance of abandoned workings would suggest that Coal Mining is the most important single influence on Fife's total population growth during the period in question. It might also be argued that the difference between the two types observed at the beginning of our period could well be accounted for by the influence of the coal industry, since the developments prior to 1755 in, for example, Dunfermline, Culross and Wemyss are well documented.

This conclusion is reinforced if we compare the growth patterns of the two average parishes with the growth pattern of the County as a whole (figure 9.3). There is an extraordinary degree of correspondence

between the curve for total population and the curve of the mean 'coal' parish. Indeed, the figures produce a positive correlation coefficient of 0.99, a virtually perfect correlation, while the correlation of total with 'non coal' figures produces a positive coefficient of 0.86.

Rather than examine the 'coal factor' through the classification of parishes, it is possible to approach it more directly. We may ask, for instance, how far changes in coal output or in numbers employed are reflected in population figures. Before the mid nineteenth century, accurate figures are not available for total output and total numbers employed, so it is necessary to resort to estimates obtained from a variety of contemporary sources. For example, Nef⁴ and later Duckham⁵ produced estimates of Fife's output in the 1790s based mainly on parish by parish surveys of the OSA. Also, we are told that in Dunfermline parish at that time 624 persons were employed for an output of 90,000 tons per annum⁶. This suggests an output of about 144 tons per annum per person employed. There is no reason to suppose that at that time other areas of the Fife coalfield had very different levels of productivity, so such snippets of information may be put together to produce the picture, admittedly incomplete, in figure 9.4.

The indication of comparatively slow growth in output and employment during the hundred years up to about 1870 suggests that the influence of the Coal Industry on population growth during that century may not be as important as our earlier discussion implies, although there were always local exceptions. Regarding Beath parish, for instance, a footnote to a table in the 1851 census records that 'The increase in population is chiefly owing to the number of hands employed at a coal and iron-stone work'⁷. Generally, though, a

mining workforce which increased from about 1750 in 1795 to 2781 in 1841 could scarcely be considered the main cause of a total population growth in the County of 53,000 during the same period. Despite the close relationship between 'coal' parish and total population, it seems that other factors were indeed at work. They are most likely to have been Agriculture and Textiles.

It is these factors hinted at by Dewdney when he points out that rural populations generally showed well-marked increases up to and in some areas beyond 1850⁸, while Smith refers to the latter in his comment that the increase of 27% that occurred between 1811 and 1831 was partly due to the fact that the new spinning mills attracted workers from the Highlands and Ireland, as well as from neighbouring counties⁹. Macdonald's look at the Linen industry supports this view. In reference to the rise of spinning mills, he says:

"Irish linen weavers were coming over to Scotland in great numbers from about 1773, partly, at least, because of the decline of the linen industry in their own country. The sudden rise in the population of Fife affords ample proof of the immigration."¹⁰

A three-factor picture of Agriculture, Textiles and Coal is implied in the 1837 entry for Largo in the New Statistical Account:

"The population formerly employed in sea-pursuits, salt-works and collieries in the South, has no doubt been diminished; but the deficiency is far more than counterbalanced by the greater numbers of hands employed in the cultivation of the land,¹¹ in manufactures, and in collieries in the North."

The levelling off of population growth in the decade 1851-1861 has already been shown to be a feature emphasised by an actual decline in 'non coal' parishes. The cause is identified by Smith as:

".....the great decline of the hand-loom weaving industry.....large numbers of people were forced to leave their homes in parishes like Newburgh, Auchtermuchty and Ceres, that had been important centres of the old domestic industry....The population of the County actually rose slightly

over the period, but the excess of births over deaths would have ensured a much greater increase than one of 4.7% had not there been a considerable loss by migration."¹²

After 1861, the County's steepening population curve appears to be more closely associated with coal mining, a feature apparent in figure 9.4. Six parishes in particular are centres of this extraordinary increase. Dunfermline, Kirkcaldy and Dysart, Beath, Ballingry, Auchterderran, and Wemyss show a total increase of 101449 persons between 1861 and 1911, which is 93% of the County's total 50-year increase. The influence of the Coal Industry in these parishes may be gauged from figure 9.5, which shows the distribution of Fife's major collieries in 1912.

The three parishes of Beath, Ballingry and Auchterderran, comprising the inland coalfield where development was particularly intense during the second half of the Nineteenth Century, show a marked correspondence between the coal output of the main local producer and the pattern of population change in the area (figure 9.6). The figures produce a positive correlation coefficient of 0.99.

Smith is in no doubt whatever as to the main influence on Fife's population at this time. Referring to the twenty years 1891-1911, he says that the main reason for the unprecedented rise in population was the mining industry¹³.

While much of the available evidence would support this view, it is pertinent to ask how far natural increase could account for the 'unprecedented rise' to which he refers. Throughout the later part of the nineteenth century, Fife's birth rate was substantially higher than the death rate, a gap which increased in the twenty years 1891-1911 as the death rate fell more steeply than the birth rate. The figures suggest that of a total increase of over 80,000 between

1891 and 1911, some 54,000 may be accounted for by natural increase. However, this estimate fails to correspond with the reciprocal figures for the number of persons born outside the County, which suggest that some 45,000 of the increase were born elsewhere, thus leaving some 35,000 of the increase to be explained by natural increase. While this is a very different figure from 54,000, it still gives an indication of the scale of the relationship between natural increase and immigration. Also, it would appear reasonable to suggest that migrant families might show the usual migrant tendency towards higher birth rates, thus producing an indirect effect as migrant labour moving to the coal mines brought with it a higher rate of natural increase, or in this case, a more slowly falling rate, than would otherwise have been the case.

In any event, immigration into the County was of very great importance in Fife's population growth in the late nineteenth century, and figure 9.7 shows a steady increase in the forty years after 1871 in the proportion of the population born outwith Fife.

Both outward and inward migration is known to have occurred earlier in the nineteenth century, but not on such an enormous scale. In Wemyss in 1838, for instance, the writer of the NSA reports:

".....in the coal department, which has also been extended, a good many houses have been lately built for the accommodation of the colliers, some of whom have come from other parts of the country."¹⁴

Nevertheless, this inward migration was enough to produce a figure in 1841 of about 13% of Fife's population born outside the county. Not all of these incomers would have come specifically to mine coal, though some undoubtedly did. Quoting the Catholic Directory of 1847, Handley cites the Forth Iron Works near Dunfermline, the Edinburgh and Northern Railway in Kirkcaldy, the coal and ironstone

mines near Lochgelly and the flax-spinning industry in general as all being influential in attracting Irish immigrant labour to Fife¹⁵.

In the great expansion of the late nineteenth century, by which time migration from Ireland was slowing down, coal mining was more of an influence in bringing in labour from the Lothians and Lanarkshire. In any case, many of the Irish had gone to coal and iron works in Lanarkshire and the West of Scotland between 1830 and 1850, a fact which may have led Bremner to write in 1868:

"(in Fife)the miners are superior in every respect to the same class in Lanarkshire and the West of Scotland generally....This arises chiefly from the fact that, while the Eastern miners are almost without exception Scotsmen, whose forefathers for several generations have followed the same avocation in the same locality, a great proportion of those in the West are Irishmen, mostly of a very rough type....."¹⁶

In the great mining expansion in Fife after about 1870, the shortage of labour was overcome by recruiting from various sources. They included the Lothians, Lanarkshire and the West, and within Fife itself. The Lothians had provided a source of labour for the mines at Fordell early in the nineteenth century, but few had remained for long. At Kelty about 1890, labour unrest prompted Charles Carlow of the Fife Coal Company to employ Lothians miners, but like their compatriots at Fordell they soon returned home¹⁷. These examples lend weight to Ashton's view which doubts that immigrant miners often became permanent settlers¹⁸. On the other hand, the transfer of miners to Blairhall from Lanarkshire by the Coltness Iron Company in 1906 seems to have been a permanent migration, and Fife's overall statistics suggest that this was the rule¹⁹.

Table 9.3 shows the main sources of migrants into Fife between 1871 and 1911 and is derived from Census data on 'Birthplaces of the People'. The actual numbers are shown together with the percentage

of Fife's total population. 'Main' sources are defined here as those areas which were the birthplace of more than 4,000 persons in Fife's Census data for 1911, and the seven areas so identified account for about three-quarters of Fife's non-native population in that year.

The first point to emerge is a confirmation of the tendency illustrated in figure 9.7, which is a steady increase in both the numbers and the proportion of residents born outwith Fife. This increase led to the incoming group forming just over 16% in 1871 but almost 33% by 1911.

Secondly, it is clear that the dominant area throughout the period in question is the Lothians, which suggests that those who came and went in Fordell and Kelty were not typical. Lothians-born persons accounted for 2.9% of Fife's population in 1871, rising steadily to 6.88% in 1911. Midlothian was actually the main source, accounting for 13,577 of the 18,424 Lothians-born group in 1911, and implying a connection with the mining areas in that County. By that year, Lanarkshire was the next largest source, with 4.67%, but had been much less significant in 1871 with only 1.06% and shows most increase in the decade 1901-1911.

Other Scottish sources are less important, but Forfar maintains a steady significance throughout, always ranking second or third, while the 'Highlands' (consisting of 11 counties) also shows a low but steady increase over the period. Perthshire reaches a peak of significance in 1891, suggesting that migration from this county was not primarily coal-motivated. Given this perspective, immigration from England and Ireland is seen to be of less importance, particularly the latter.

Despite these high levels of immigration, it must be remembered that the majority of miners in Fife were born in that county, and

Stephen points out that even in the burgeoning town of Cowdenbeath, some 70% of the miners came from Fife while further West in Torryburn, 60% were native Fifers²⁰. Many of these men must have been recruited from other occupations, and Taylor illustrates this in quoting figures from Bowhill:

"Of 1398 men employed underground at Bowhill Colliery, Fife, in 1907, 948 (68 per cent) had begun their working lives underground and 21 were former surface workers. 100 of the remainder had been general labourers, 60 were former farm-workers, 18 were ex-servicemen and there were 75 others of varied occupational background."²¹

Unfortunately, we do not know how many were native Fifers.

In looking at the first characteristic of Fife's changing population, its growth pattern, we can see that up to 1851 the County experienced a growth only partly explained by the development of the Coal Industry. However, in 1851-1861 mining was to more than make up for the decline in the domestic textile industry. After 1861, Fife's population growth was more closely correlated with the expansion of coal mining in which growth in output is closely paralleled by growth in numbers employed, and where both immigration and local recruitment are major factors.

Characteristic 2: Population Distribution

The second major characteristic of Fife's population is the changing distribution from a fairly even spread in 1755 to a distribution in which the Western parishes show an emphatic dominance. The extent of this shift may be illustrated by the fact that in 1755, the Eastern part of Fife contained 52% of the population, with 48% in the West. By 1911 there was a very much larger total population, but the West now contained no less than 80% of it. Although it is conventional to refer to 'West' Fife, the map showing the shifting

centre of gravity of population (figure 9.8) illustrates that the shift was really Southward. A short Westward movement between 1755 and 1801 was succeeded by a shift directly South in the 50 years to 1851. The second half of the nineteenth century saw a very substantial move in the same direction, which suggests that population growth in that period reflected the mining developments in Dunfermline/Cowdenbeath on the one hand and the balancing developments in Wemyss/Scoonie on the other. A series of more detailed distribution maps paint a more sophisticated picture (figures 9.9 - 9.13).

In 1755 (figure 9.9) there was an even distribution of population although indistinct concentrations were already becoming evident. Dunfermline, Kirkcaldy/Wemyss, Newburgh, Cupar, St Andrews and St Leonards, and, more clearly, Anstruther/Pittenweem, were more densely settled at that time, a distribution perhaps connected with the location of Royal Burghs. By 1801 (figure 9.10) the pattern was emerging more clearly, with Dunfermline, Kirkcaldy, Anstruther, Cupar and Newburgh showing distinct concentrations. By 1851 (figure 9.11) the growth in total population is more apparent while the earlier concentrations have become quite emphatic. The 1901 distribution shows further development (figure 9.12). In particular, the emergence of a very dense belt from Scoonie along the coast to Kirkcaldy and the appearance of an area of high concentration between Dunfermline and Kirkcaldy where the inland coalfield parishes of Beath, Ballingry and Auchterderran were becoming prominent, especially the first of these. Only 10 years later in 1911 there was a definite intensification of this pattern (figure 9.13). Population in Fife was clearly dominated by the South and West, with a remarkable band running from Dunfermline parish in the West, through Beath, Ballingry, Auchterderran, Kirkcaldy

and Dysart and Wemyss parishes, to terminate with Scoonie in the East. This distribution may be usefully compared with the location of pits shown in figure 9.5.

In seeking an explanation for this changing distribution, it was felt that parishes might fall into groups according to their pattern of population change over the 16 decades 1755-1911. If such 'clusters' of parishes could be identified, their membership might throw some light on the relationship between population distribution and coal mining. The technique adopted was a simple graphical one where a graph of population change was plotted for each of the 60 parishes and the results were overlaid. The resulting composite graph is shown in figure 9.14.

Four types or 'clusters' of parishes may be identified (see Table 9.4 and figure 9.15). First, Kirkcaldy and Dunfermline are outstanding as two parishes with the largest population throughout the period. Second, a small group of parishes show a remarkably high rate of increase during the twenty years 1891-1911. They are Auchterderran, Beath, Wemyss and, less emphatically, Ballingry and Scoonie. These two 'clusters' consist entirely of 'coal' parishes and together form the dense belt of population first identified in figure 9.12. A third cluster is those parishes which maintain a fairly low but steady population throughout (ie less than 1,000). Examples are Kilmany, Flisk, Moonzie and Logie, but in all there are twelve in this category. Only one of these is in West Fife and that parish (Auchtertool) is the only 'coal' parish of the twelve. The remaining 41 parishes form a large and more varied group, hardly a 'cluster', in which no clear coal/population relationship is apparent. Consequently, this group contains most of the parishes where population peaked in mid nineteenth century (1831-1871). In fact, of 23 parishes which peaked in that period, no fewer than 19

are found in this group. Clearly, one would expect to find most of the mid-century peaks in East Fife, and figure 9.15 shows that this is indeed the case, with only four of the 23 to be found in the West, a fact which points to the E-W divide in Fife becoming already apparent in mid-century, long before the more emphatic contrast of later decades.

In general, it may be seen that expansion of the coal-related population came late on the inland coalfield, where large-scale mining developments had to await the coming of the railway in mid-century. Also, the capital resources of large companies were required before major sinkings could be contemplated. The growth further East, in Wemyss and Scoonie, is closely related to mining expansion for export, particularly through the purpose-built port of Methil. In summary, the major change in Fife's population distribution described above, namely the change from a comparatively even spread to a pattern of dominance by the West, is without doubt one of the most significant geographical effects of mining development in Fife.

Characteristic 3: The Growth of Towns

With regard to the third characteristic of Fife's changing population, the growth of towns, we may try to assess the influence of the coal industry by first of all identifying those Burghs which enjoyed the greatest increase.

Figures 9.16 and 9.17 show the growth in Burgh populations between the years 1851 and 1911. The clearest feature of the 1851 pattern is its relatively even spread throughout the County, mainly in towns of less than 3,000. Indeed, at that date only four

settlements were larger than this figure: Dunfermline (8,577), Kirkcaldy and Dysart - then separate (6,703), St Andrews (4,730), and Cupar (4,005). Two of these, Dunfermline and Kirkcaldy/Dysart, were already centres of the mining industry. In fact, Dunfermline was the location of Fife's earliest documented coal mining when, in 1291, the monks of the Abbey were granted a Charter to mine coal in the lands of Pittencrieff²². The New Statistical Account records that by 1842 nearly 3,000 people were dependent on five collieries in the parish, all of which appear to have been in the vicinity of Dunfermline Town²³. Butt claims that there are at least eleven disused colliery shafts in the Burgh, mostly dating from about 1860²⁴, and evidence to the Children's Employment Commission reports that 1181 people were employed in the five collieries of 1842²⁵, while the 1851 and 1861 Census enumeration books identify 'coalminers' as numbering 707 and 921 respectively. On the whole, it seems reasonable to suppose that many of these mining families were resident within the Burgh.

Kirkcaldy and Dysart was really two communities in 1851, each smaller than Dunfermline, and both located in a neighbourhood which employed fewer miners, despite the fact that coal mining is reported to predate the OSA by 300 years, and Barrowman states that coal was worked at Dysart as early as 1406²⁶. The Children's Employment Commission records 126 miners in the parishes of Kirkcaldy and Dysart in 1842²⁷, but this had risen to 176 by 1851 and in the next census in 1861, the total was still only 208, more than half of which were in Dysart parish. It seems that Kirkcaldy owed its mid-century demographic prominence to its good harbour and varied industry, rather than to coal mining.

Cupar and St Andrews owe nothing at all to coal mining. The former was a market town of some 4,000 people conveniently situated in a rich agricultural area and a centre of the handloom weaving industry. The latter was an early ecclesiastical centre, but by 1851 was already beginning to rely on the long-term bases of its prosperity - University, Golf and Tourism. Thus, even as late as 1851, the towns of Fife show only a limited relationship with developments in the coal industry. By 1911, however, the picture had changed considerably. The expanding population in the West and South was reflected in the growth of towns in this part of Fife and, in particular, four communities had expanded dramatically. Dunfermline and Kirkcaldy and Dysart, the latter two now effectively merged into one urban area, were significantly larger than any other towns with respective populations of 28,103 and 43,798. Precisely how much of this growth is due to coal mining is difficult to say without a detailed analysis of census data as yet unavailable.

However, it does seem that coal mining was a more significant factor in Dunfermline than in Kirkcaldy. For example, the 'Catalogue of Plans of Abandoned Mines' has 122 entries for the former parish but only 40 for the latter²⁸. Textiles was very important in both towns but while Dunfermline's economy was dominated by Textiles, Coal and Dockyard, Kirkcaldy enjoyed a more varied industrial base. According to Smith:

"...Kirkcaldy, and its neighbour, have long possessed an unusually varied, and generally thriving, assortment of industries. Throughout much of the nineteenth century, the chief industry of Kirkcaldy comprised the spinning of Flax and the weaving of linen, but there were also several important branches of engineering - iron- and brass-founding, boiler-making and machine-making - as well as breweries, distilleries, tanneries and cooperages, and manufacturers of....chemicals, nails,

tobacco, salt, rope and twine....Shipbuilding yards operated sporadically while potteries and brick and tile works were to be found...As the century ran its course, mining became a large-scale employer, while linoleum gradually showed signs of the position of pre-eminence it was later to occupy."²⁹

The other two expanded communities on the map of 1911, Cowdenbeath/Lochgelly and Methil, show a coal mining influence which was much more exclusive. Cowdenbeath and Lochgelly, both Burghs on the interior coalfield, had grown from 1861 populations of 1148 and 1629 respectively to 14,029 and 9,149. A close examination of their growth patterns is instructive (figure 9.18).

Lochgelly grew quite steeply at first, and Brown and Westwater are in no doubt as to the reason:

"In the decade of the 50s (Lochgelly) was suddenly transformed from a village of weavers and husbandmen and a score of miners to become the largest coal and iron producing centre in Fife. The change was brought about by the exploitation of its mineral wealth."³⁰

A slowing down occurred in the decade after 1871, apparently due to the fading of the iron industry, but coal soon asserted itself and population again rose steeply after 1881. This fact throws some doubt on Cunningham's view of Lochgelly's population: 'Because of developments by the Iron and Coal Company, the progress between 1870 and 1877 was very great.....'³¹.

Cowdenbeath seems to have enjoyed a slower start in mid-century but grew steeply from 1871 onwards so that it had overtaken Lochgelly a decade later. The population continued to rise very steeply, especially 1901-1911, and there can be no doubt that the parallel Cunningham draws between Cowdenbeath's growth and colliery developments of the Fife Coal Company after 1872 is an accurate one³².

The fourth outstanding growth area of the 1911 map is Methil and Buckhaven. Originally three separate villages, the Methil, Buckhaven

and Innerleven communities had depended mainly on Coal, Salt and Fishing for their seventeenth-century prosperity. Indeed, Nef identifies Methil as one of a group of settlements which owed their existence to the development of the coal trade after 1550³³. By the mid nineteenth century, however, they had experienced some decline, although in 1861 they could muster a total population of no less than 2824. In the 1860s, however, the coal industry began to revive and Methil's role as a coal port expanded, so that in 1913 total shipments amounted to 3,224,298 tons. The implication of this enormous development for population growth is quite clear, and the Burgh increased its population to 6247 in 1891. More dramatically it rose from 8,000 to 15,149 between 1901 and 1911, a growth for which the developing coal trade provides the only satisfactory explanation.

To sum up, we have attempted to isolate the 'coal factor' in Fife's pattern of population change between Dr Webster's Census of 1755 and the National Census of 1911, thus covering virtually the whole of our period 1750-1914. We have examined coal mining activity in relation to the three major characteristics of Fife's demographic pattern and may conclude that regarding growth, the 'coal factor' is of prime importance after the mid nineteenth century but prior to that stage must be put in perspective with other major influences, particularly Agriculture and Textiles. With reference to Fife's changing distribution, particularly the shift from a substantially even distribution to one of concentration in the West and South, the coal industry is a factor of vital importance. Finally, the growth of towns in Fife has been shown to be significantly influenced by the state of coal mining in the County, though with local variations.

Given that population change is a major aspect of Regional Development and that Fife's demography has been closely related to developments in the coal industry, it follows that Fife's regional development, as exemplified by population change, has been strongly influenced by the progress of the coal industry. To the extent that mining development depended on the innovation of mining technology, then regional development must be seen as having been influenced by the latter.

TABLE 9.1POPULATION OF FIFE - DECENNIAL INCREASES 1755 - 1911

Period	Decennial increase	Stage
1755 - 1791	1570 (mean)	I
1791 - 1801	6519	II
1801 - 1811	7529	
1811 - 1821	13286	III
1821 - 1831	14283	
1831 - 1841	11301	
1841 - 1851	13406	
1851 - 1861	1224	IV
1861 - 1871	5965	V
1871 - 1881	11197	
1881 - 1891	15415	
1891 - 1901	31491	
1901 - 1911	48896	

TABLE 9.2 - CLASSIFICATION OF PARISHES INTO 'COAL' AND 'NON COAL'

Parish	<u>A</u>	<u>B</u>	Classification C = coal
Abdie	0	0	
Aberdour	20	85	C
Anstruther Easter	0	0	
Anstruther Wester	1	0	
Auchterderran	59	382	C
Auchtermuchty	0	0	
Auchtertool	9	10	C
Ballingry	41	38	C
Balmerino	0	0	
Beath	87	136	C
Burntisland	3	0	
Cameron	21	33	C
Carnbee	10	20	C
Carnock	21	162	C
Ceres	14	2	C
Collessie	0	0	
Crail	0	0	
Creich	0	0	
Culross	38	43	C
Cults	0	0	
Cupar	0	0	
Dairsie	0	0	
Dalgety	9	181	C
Dumbog	0	0	
Dunfermline	122	921	C
Dunino	0	0	
Elie	1	0	
Falkland	0	0	
Ferry-Port-on-Craig	0	0	
Flisk	0	0	
Forgan	0	0	
Inverkeithing	9	0	C
Kemback	0	4	
Kennoway	4	7	
Kettle	7	19	C

TABLE 9.2 - Continued

Parish	<u>A</u>	<u>B</u>	Classification C = coal
Kilconquhar	19	60	C
Kilmany	0	0	
Kilrenny	0	0	
Kinghorn	2	0	
Kinglassie	15	42	C
Kingsbarns	0	0	
Kirkcaldy and Dysart	40	208	C
Largo	12	37	C
Leslie	9	3	C
Leuchars	0	0	
Logie	0	0	
Markinch	34	91	C
Monimail	0	0	
Moonzie	0	0	
Newburgh	0	0	
Newburn	0	0	
Pittenweem	0	0	
St Andrews & St Leonards	3	7	
St Monans	2	0	
Saline	28	83	C
Scoonie	12	10	C
Strathmiglo	0	0	
Torryburn	18	9	C
Tulliallan	12	33	C
Wemyss	69	278	C

A - Number of entries in the 'Catalogue of Plans of Abandoned Mines'

B - Number of 'Coalminer' or 'Collier' entries in 1861 Census enumeration books

TABLE 9.3 - MAIN SOURCES OF MIGRANTS INTO FIFE 1871 - 1911

(shown as number of persons - upper figure - and percentage of Fife's total population at that date - lower figure)

Birthplace		1871	1881	1891	1901	1911
England	no	2177	2636	3453	4882	8358
	%	1.35	1.53	1.84	2.23	3.12
Ireland	no	1632	1475	1732	2062	4264
	%	1.02	0.85	0.92	0.94	1.59
Lothians	no	4757	6057	8712	12767	18424
	%	2.96	3.52	4.65	5.83	6.88
Lanarks	no	1708	2697	4297	6402	12490
	%	1.06	1.57	2.29	2.92	4.67
Forfar	no	3346	4443	5544	8214	10768
	%	2.08	2.58	2.96	3.75	4.02
Highlands*	no	2271	2960	3664	4992	6715
	%	1.41	1.72	1.96	2.28	2.51
Perthshire	no	4040	4316	6432	5030	6260
	%	2.51	2.51	3.43	2.30	2.34
Fife	no	134662	139573	145745	160897	180721
	%	83.78	81.18	77.79	73.52	67.50

* Comprising the counties of Aberdeenshire, Banff, Caithness, Elgin, Inverness, Kincardine, Nairn, Orkney, Ross & Cromarty, Shetland, Sutherland.

TABLE 9.4 - PARISHES CLASSIFIED BY DEMOGRAPHIC PATTERN

Type	1	2	3	4
	• Dunfermline	• Beath	Anstruther (W)	Abdie
	• Kirkcaldy & Dysart	• Ballingry	• Auchtertool	• Aberdour
		• Auchterderran	Creich	Anstruther (E)
		• Wemyss	Cults	Auchtermuchty
		• Scoonie	Dairsie	Balmerino
			Dunbog	Burntisland
			Dunino	• Cameron
			Flisk	• Carnock
			Kilmany	• Carnbee
			Logie	• Ceres
			Moonzie	Collessie
			Newburn	Crail
				Culross
				Cupar
				• Dalgety
				Elie
				Falkland
				Ferry-Port-on-
				Craig
				Forgan
				• Inverkeithing
				Kemback
				Kennoway
				• Kettle
				• Kilconquhar
				Kilrenny
				Kinghorn
				• Kinglassie
				Kingsbarns
				• Largo
				• Leslie
				Leuchars
				• Markinch
				Monimail
				Newburgh
				Pittenweem
				St Andrews & St
				Leonards
				St Monans
				• Saline
				Strathmiglo
				• Torryburn
				• Tulliallan

• 'coal' parish

Figure 9.1 POPULATION GROWTH (1755-1911)

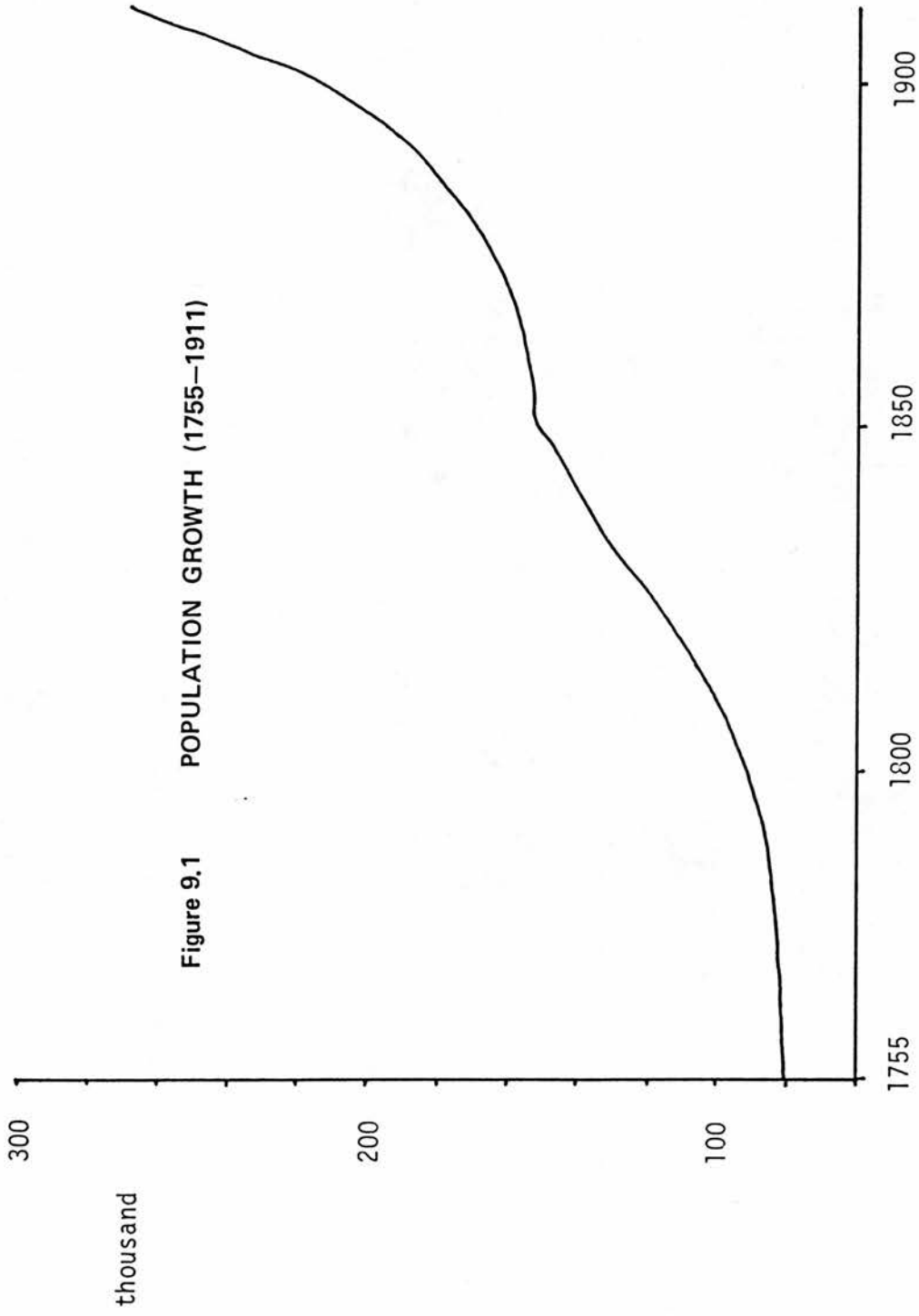
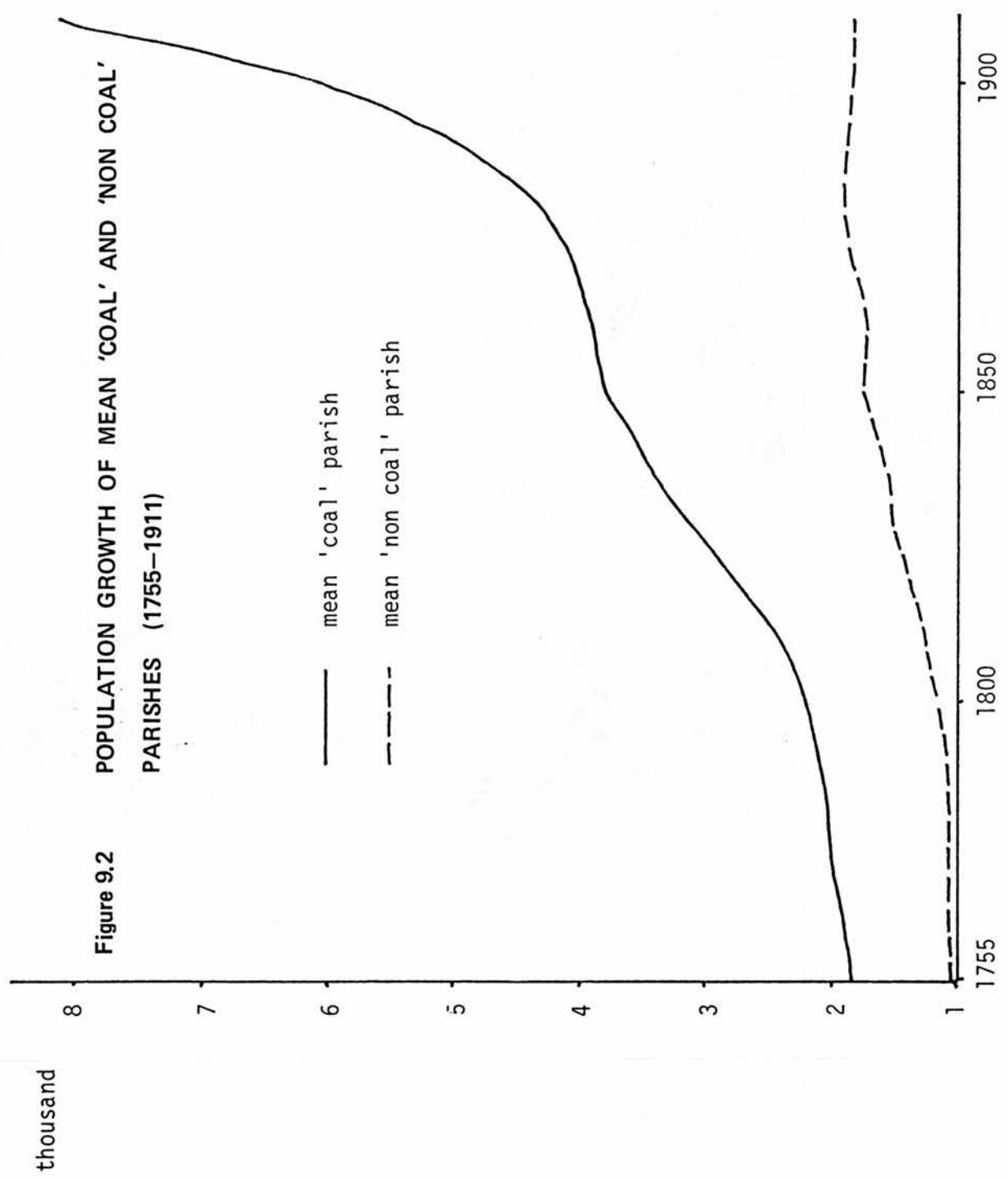
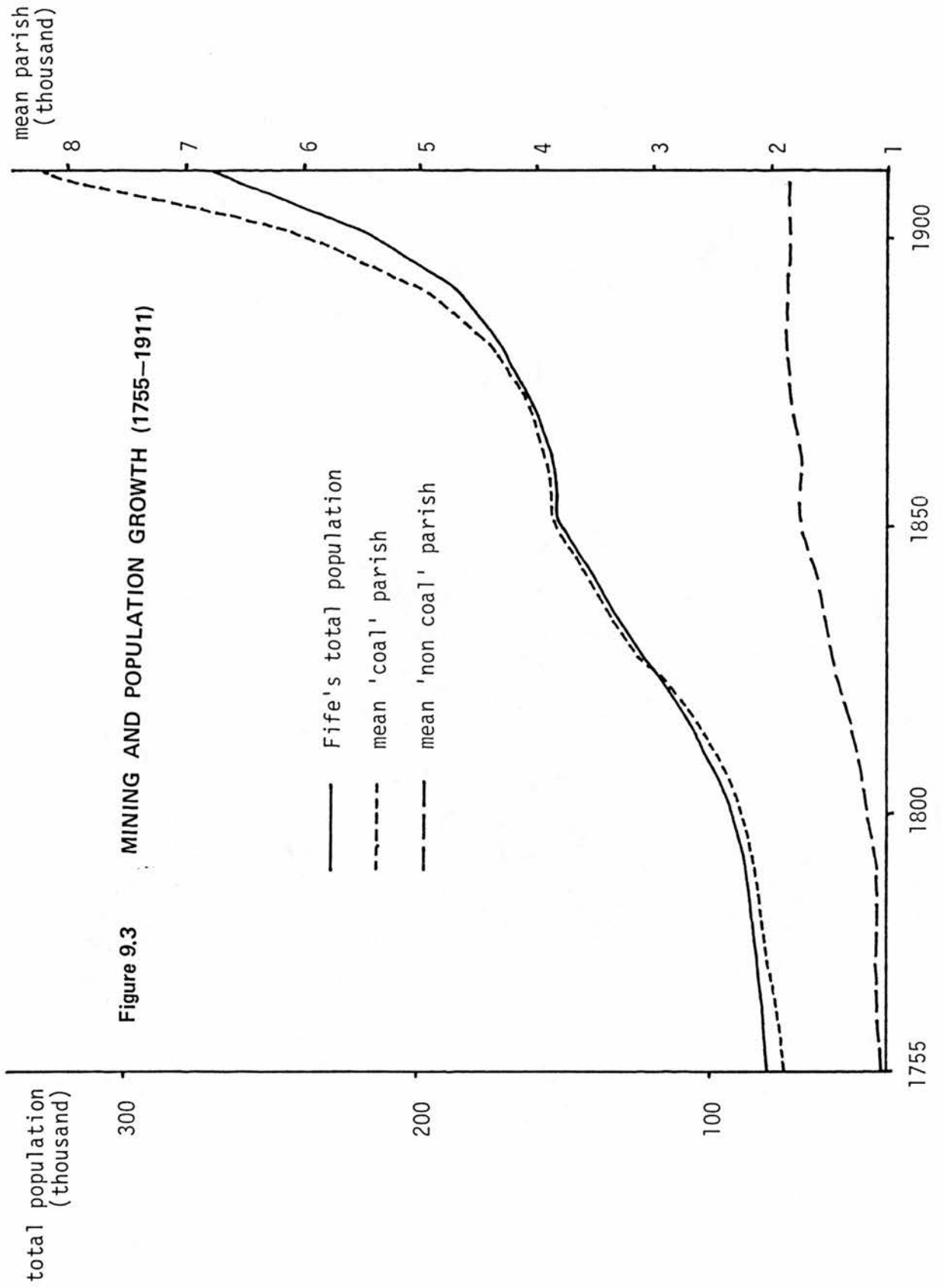


Figure 9.2 POPULATION GROWTH OF MEAN 'COAL' AND 'NON COAL' PARISHES (1755-1911)





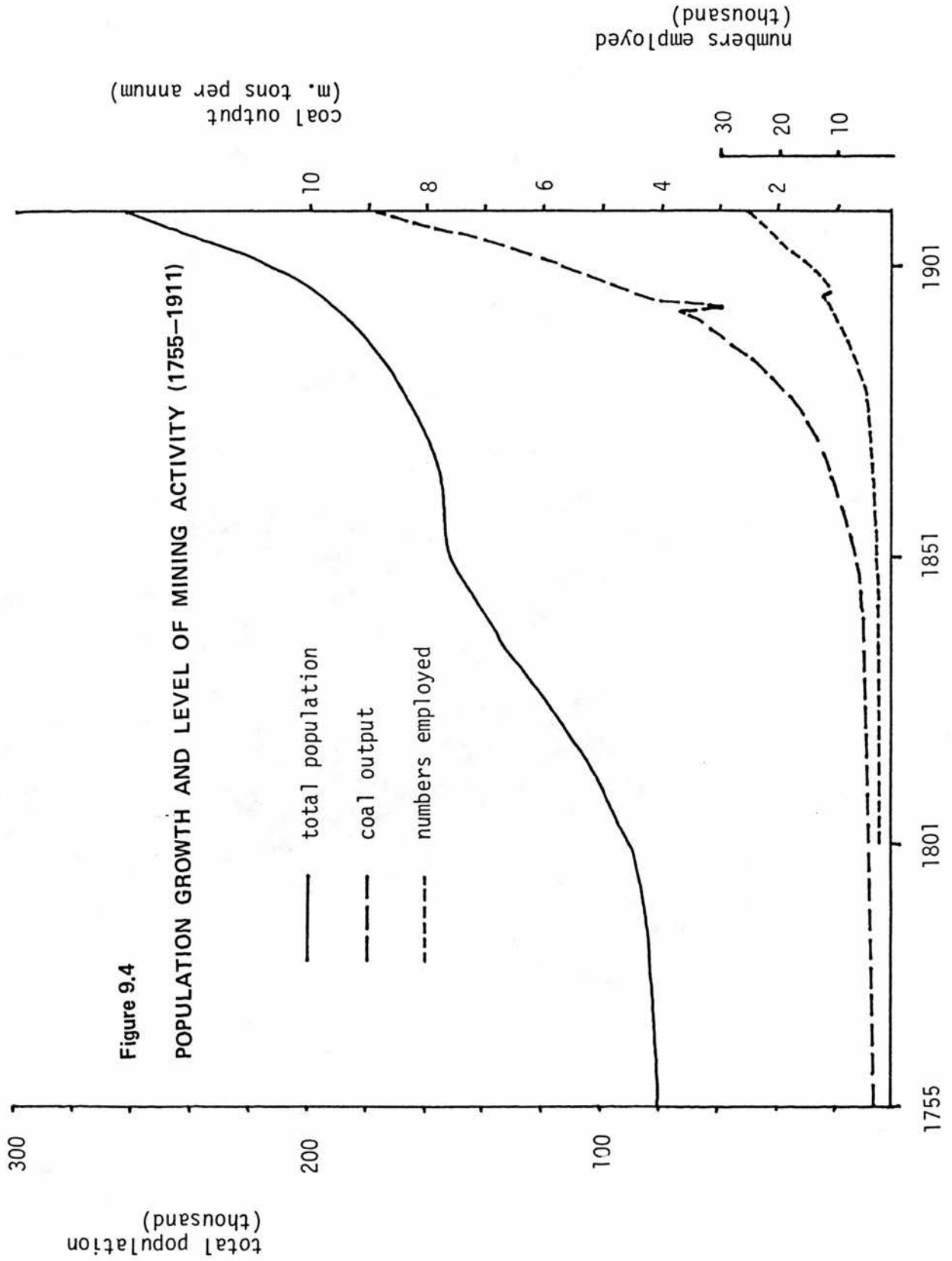


Figure 9.5

POPULATION GROWTH AND LOCATION OF MINING ACTIVITY

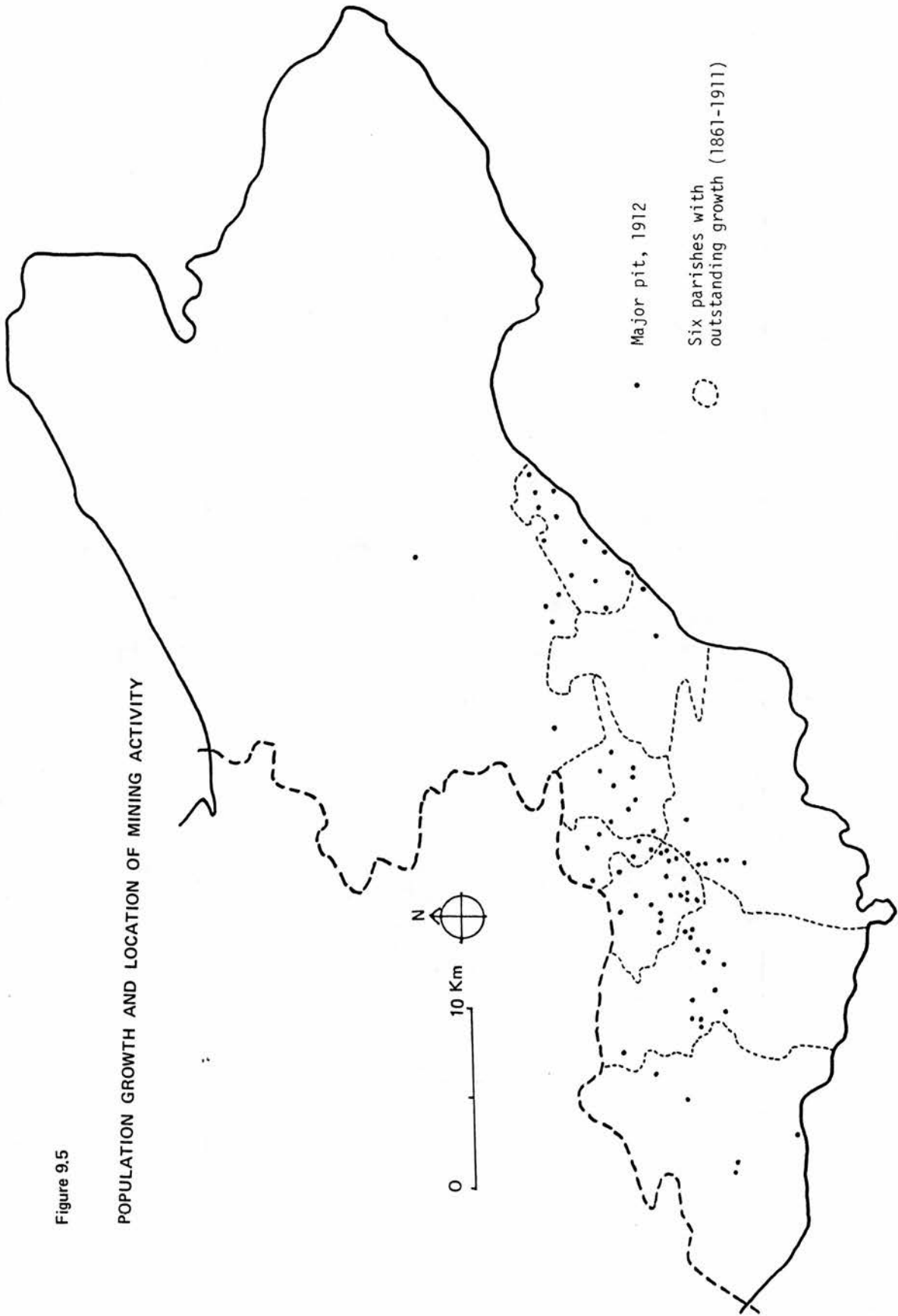


Figure 9.6 POPULATION OF BEATH, BALLINGRY AND AUCHTERDERRAN PARISHES COMPARED WITH LOCAL COAL OUTPUT

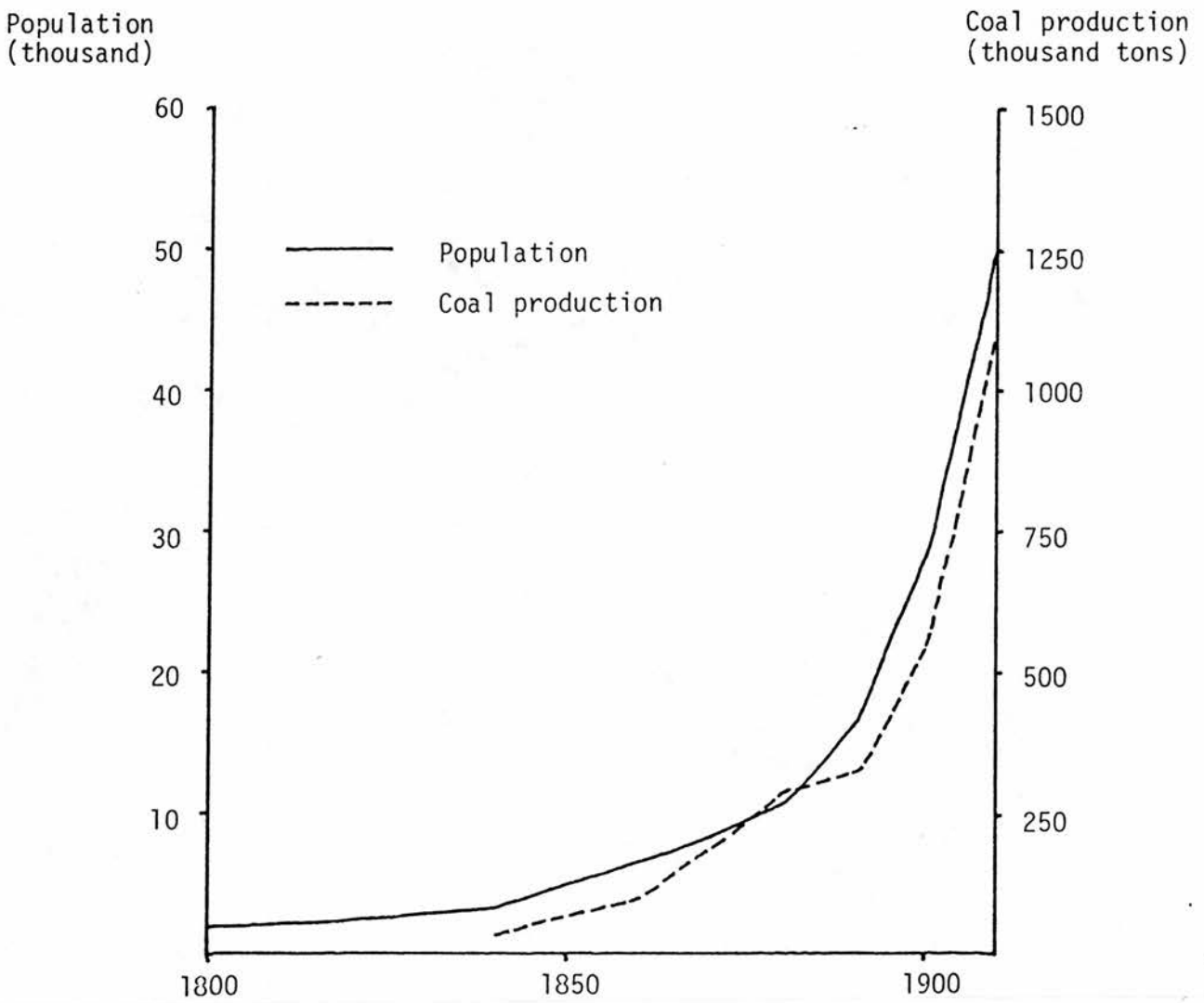
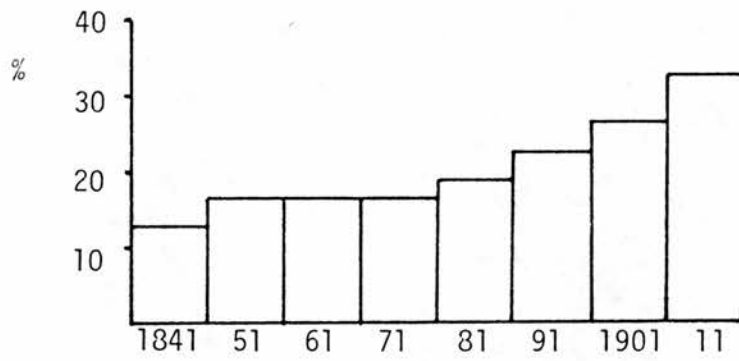


Figure 9.7 **PROPORTION OF POPULATION BORN OUTWITH FIFE**



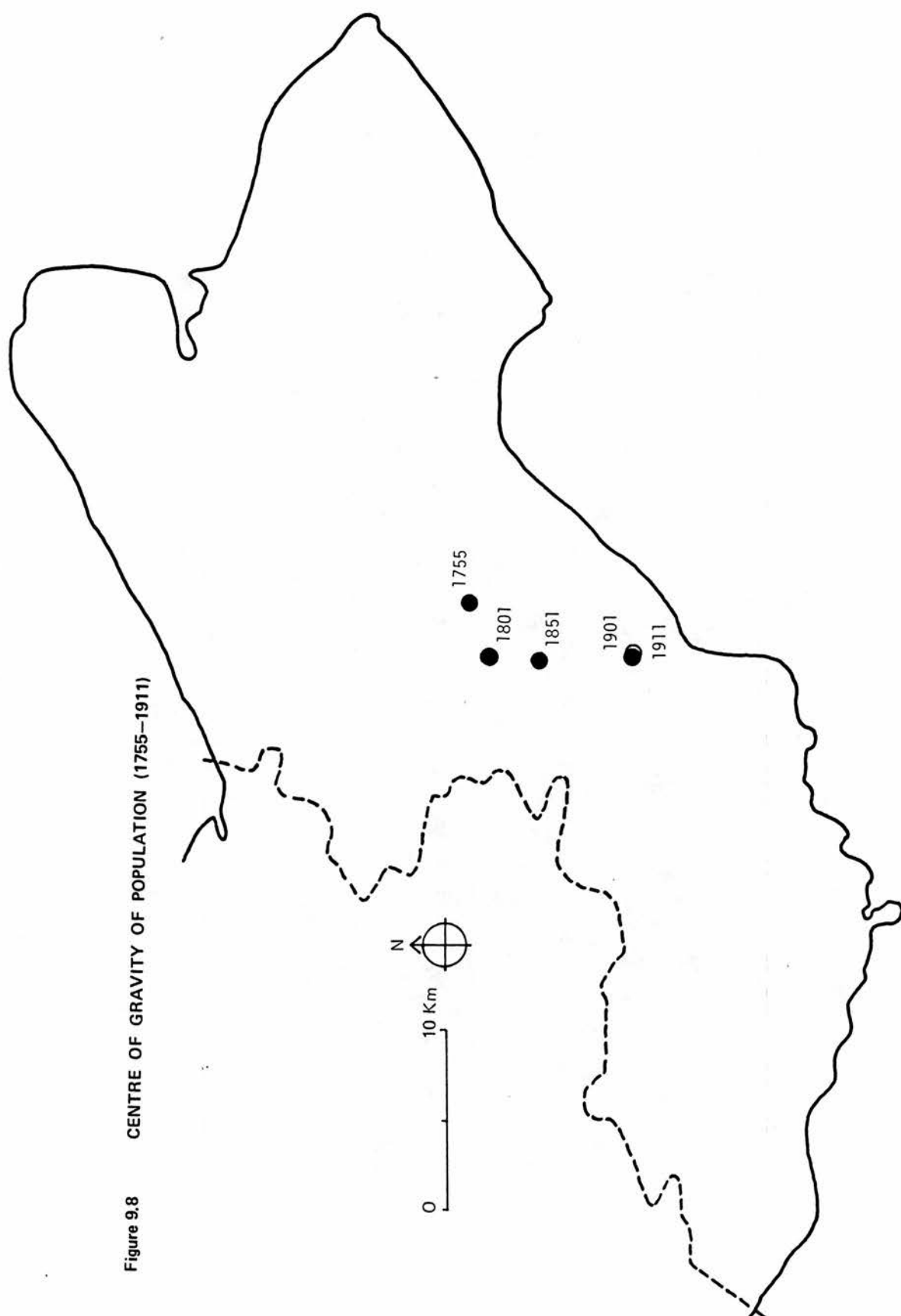


Figure 9.8 CENTRE OF GRAVITY OF POPULATION (1755-1911)

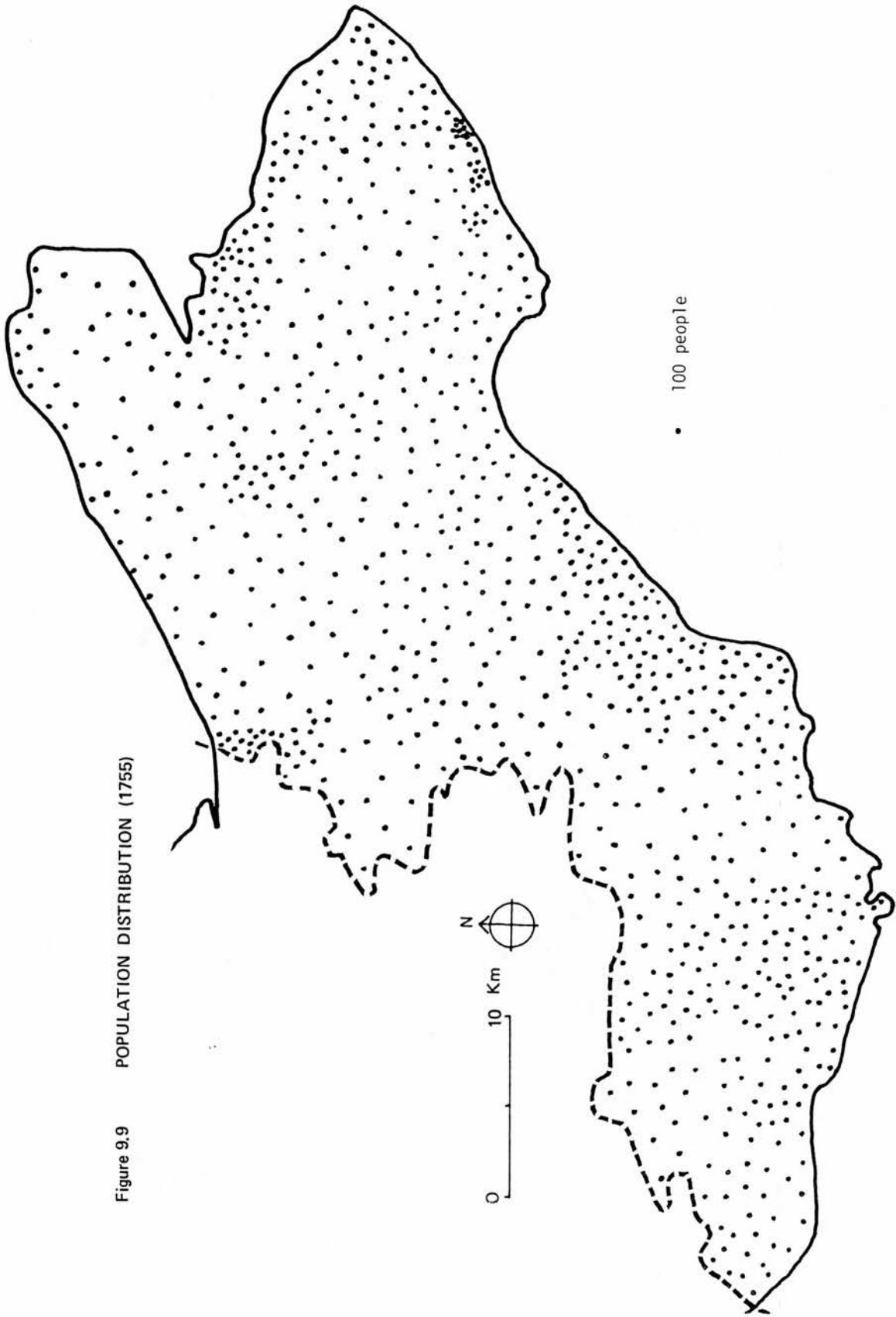


Figure 9.9 POPULATION DISTRIBUTION (1755)

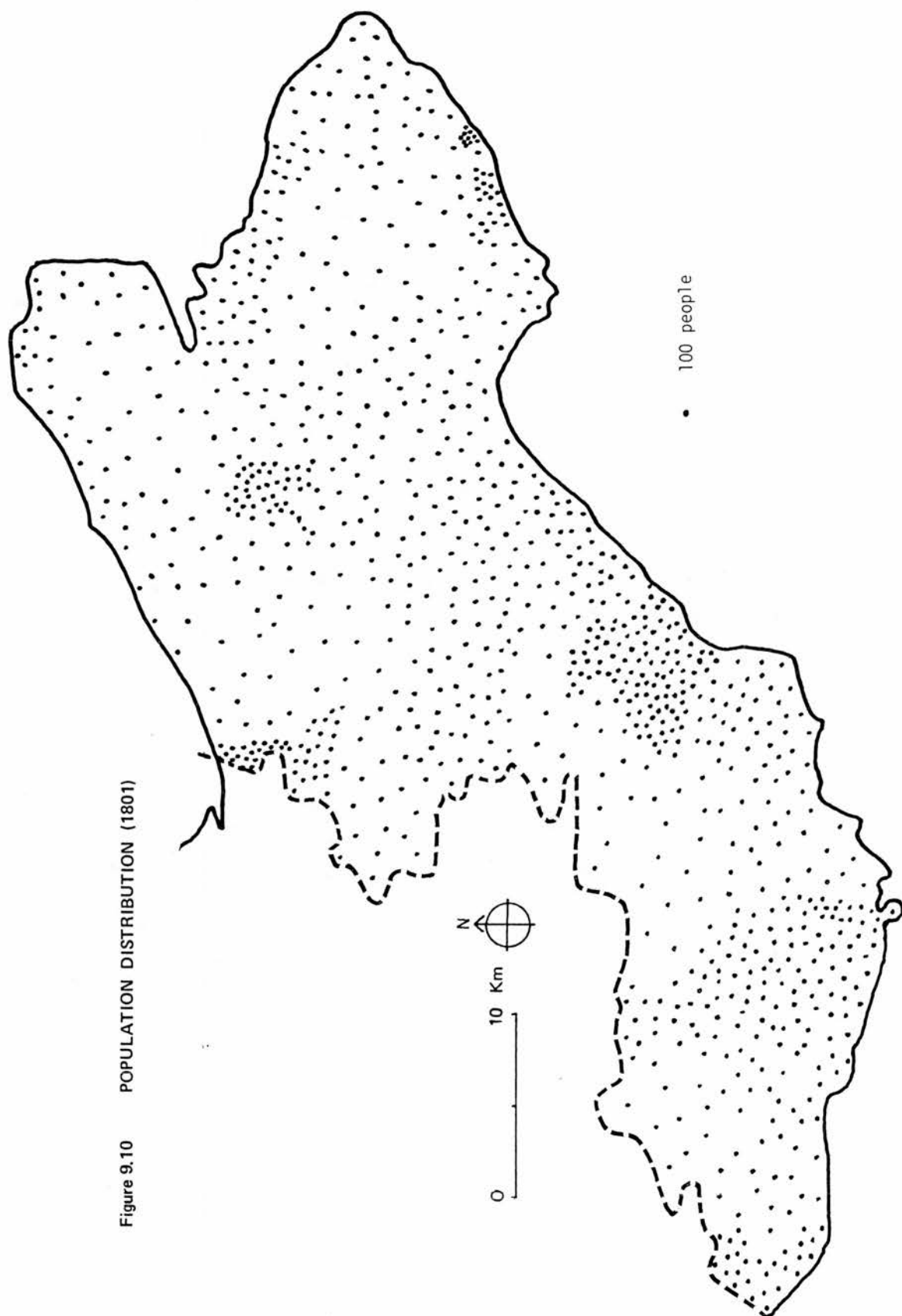


Figure 9.10 POPULATION DISTRIBUTION (1801)

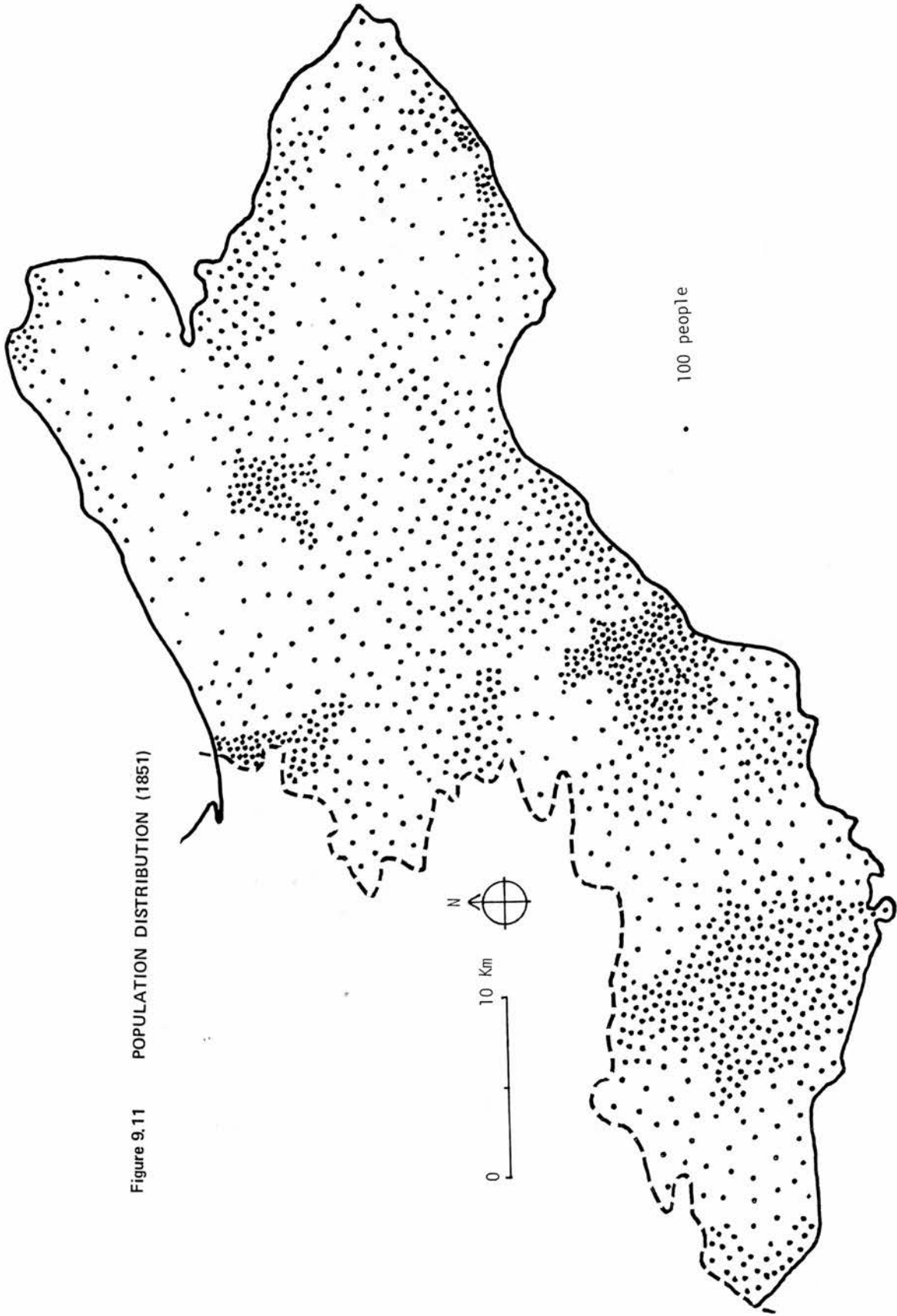
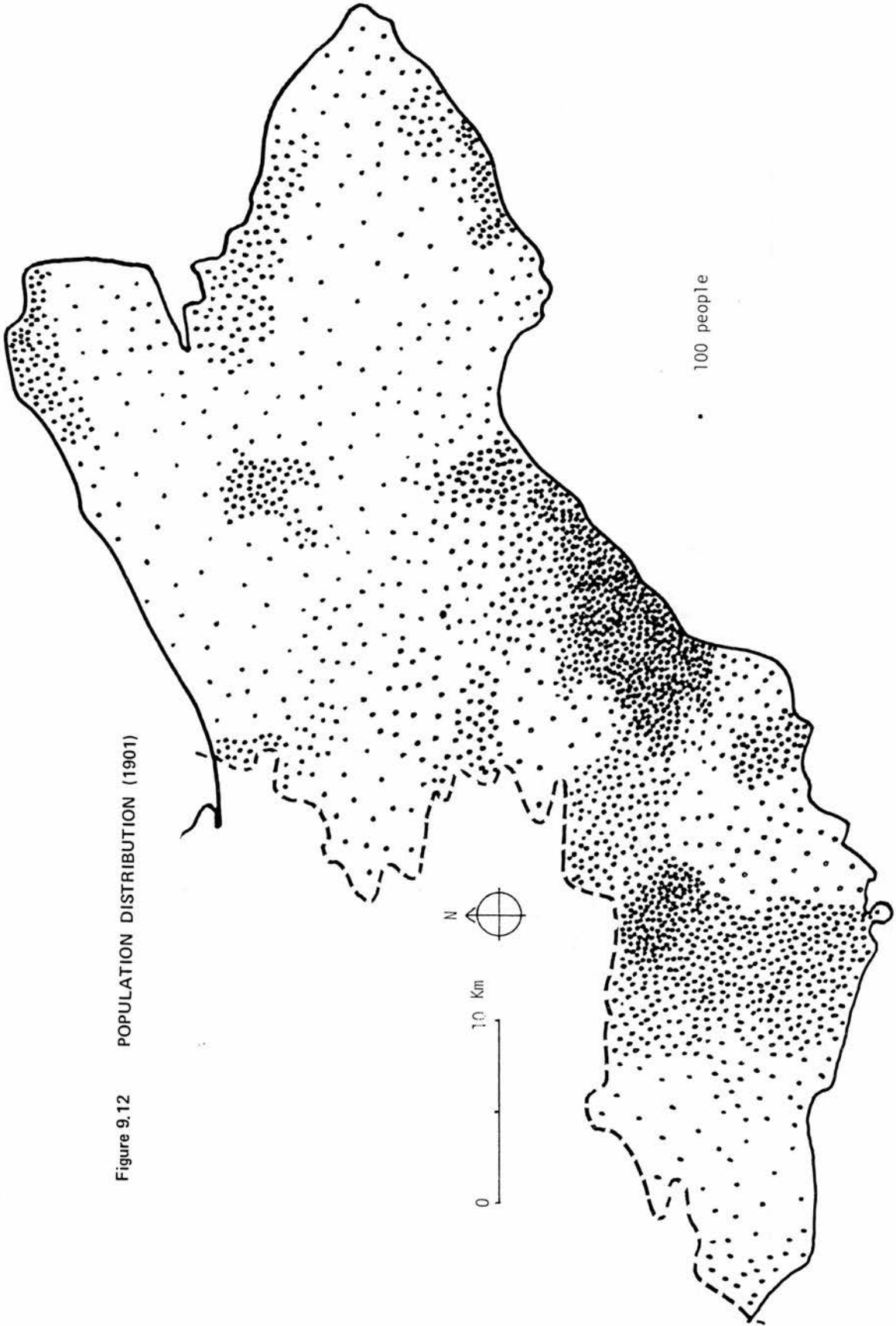


Figure 9.11 POPULATION DISTRIBUTION (1851)



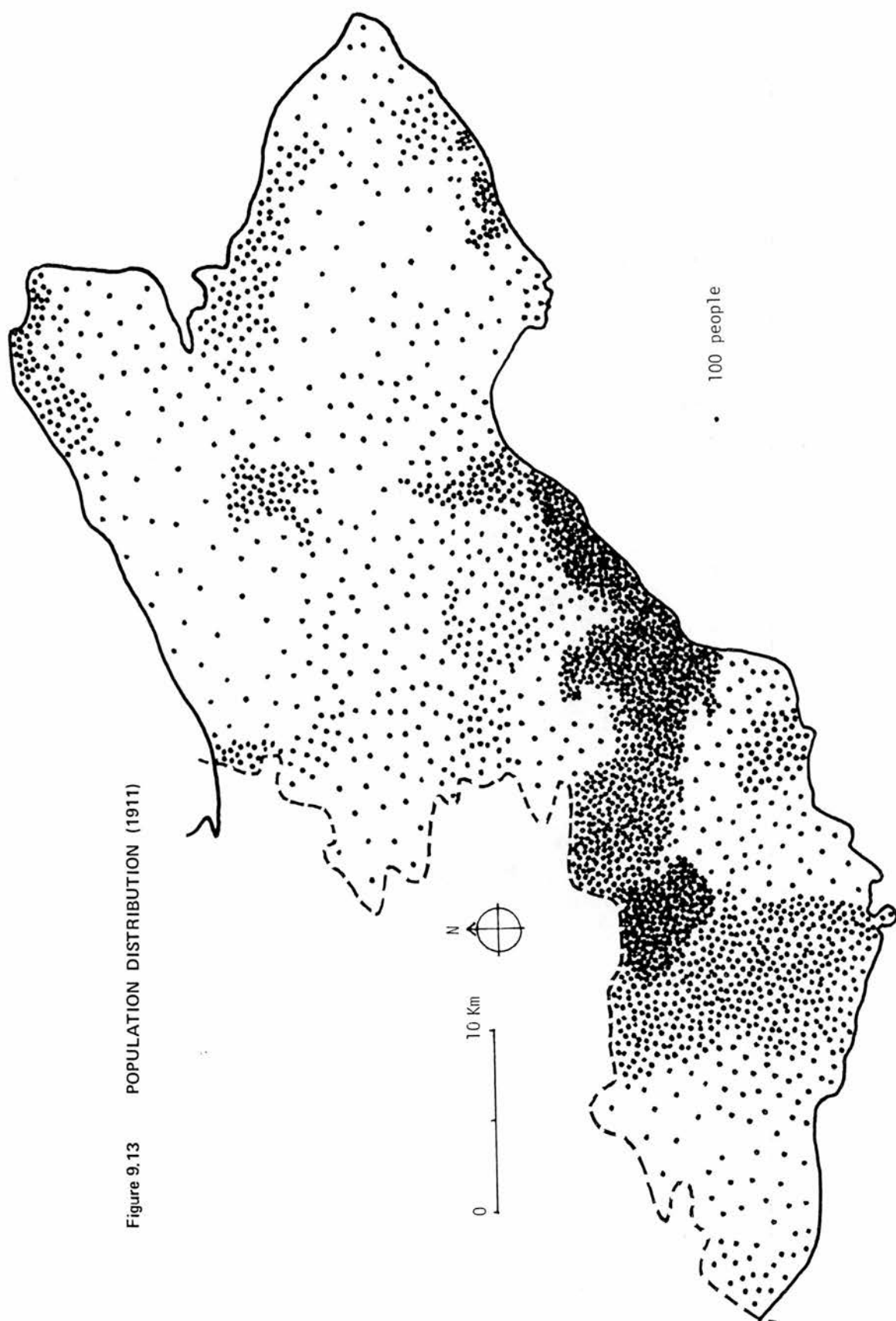


Figure 9.14

OVERLAY OF POPULATION CHANGE IN ALL PARISHES (1755–1911)

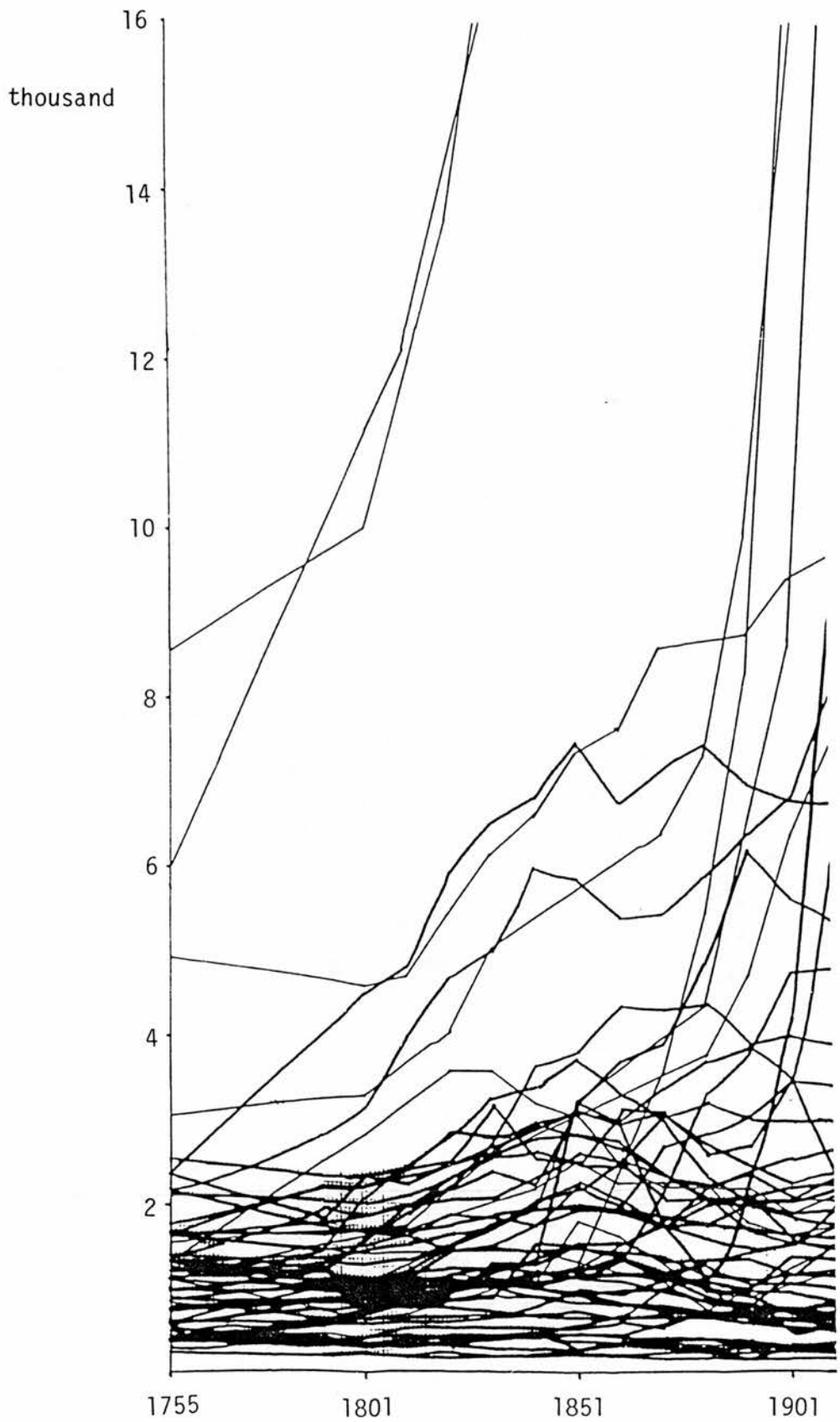
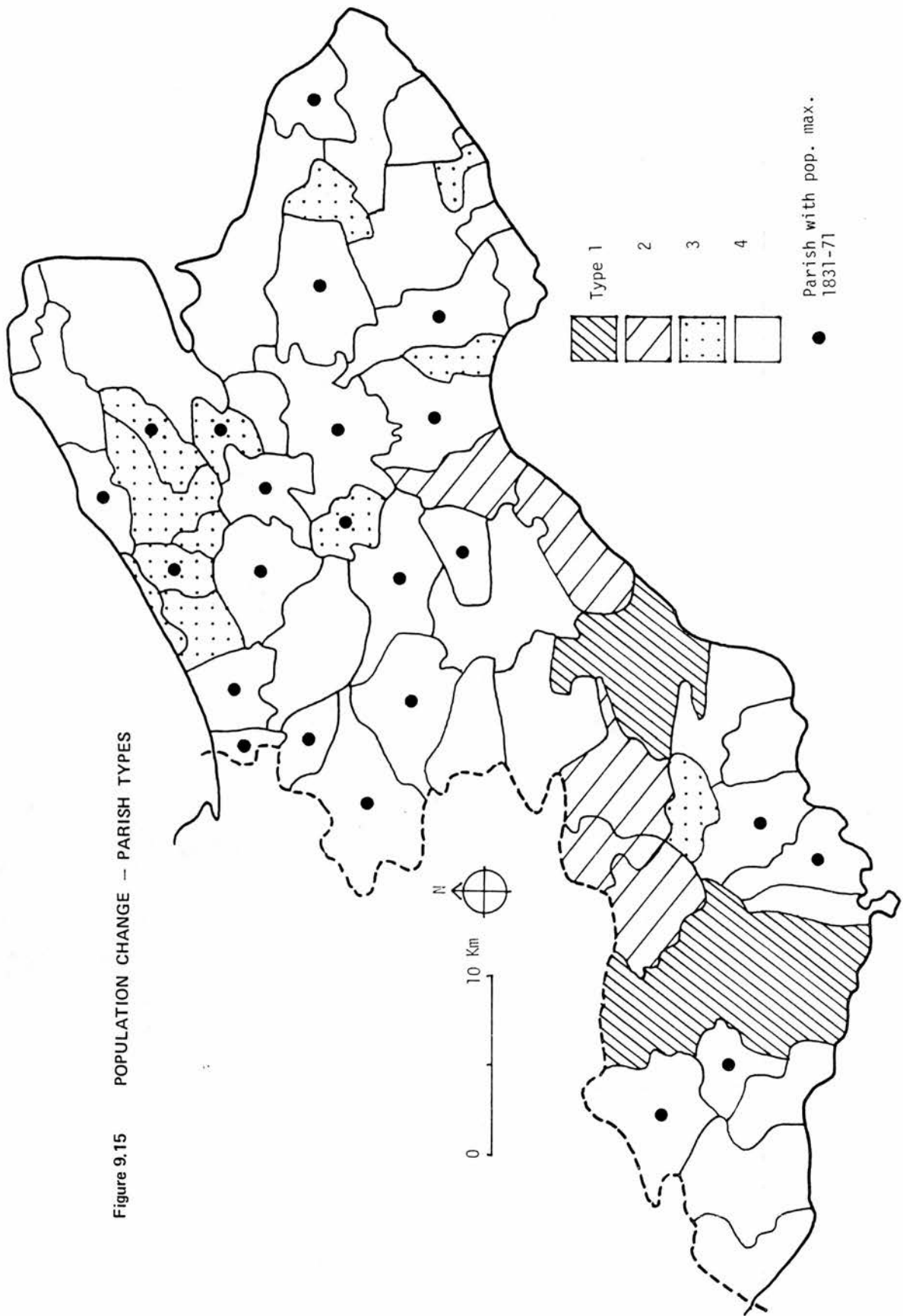


Figure 9.15 POPULATION CHANGE — PARISH TYPES



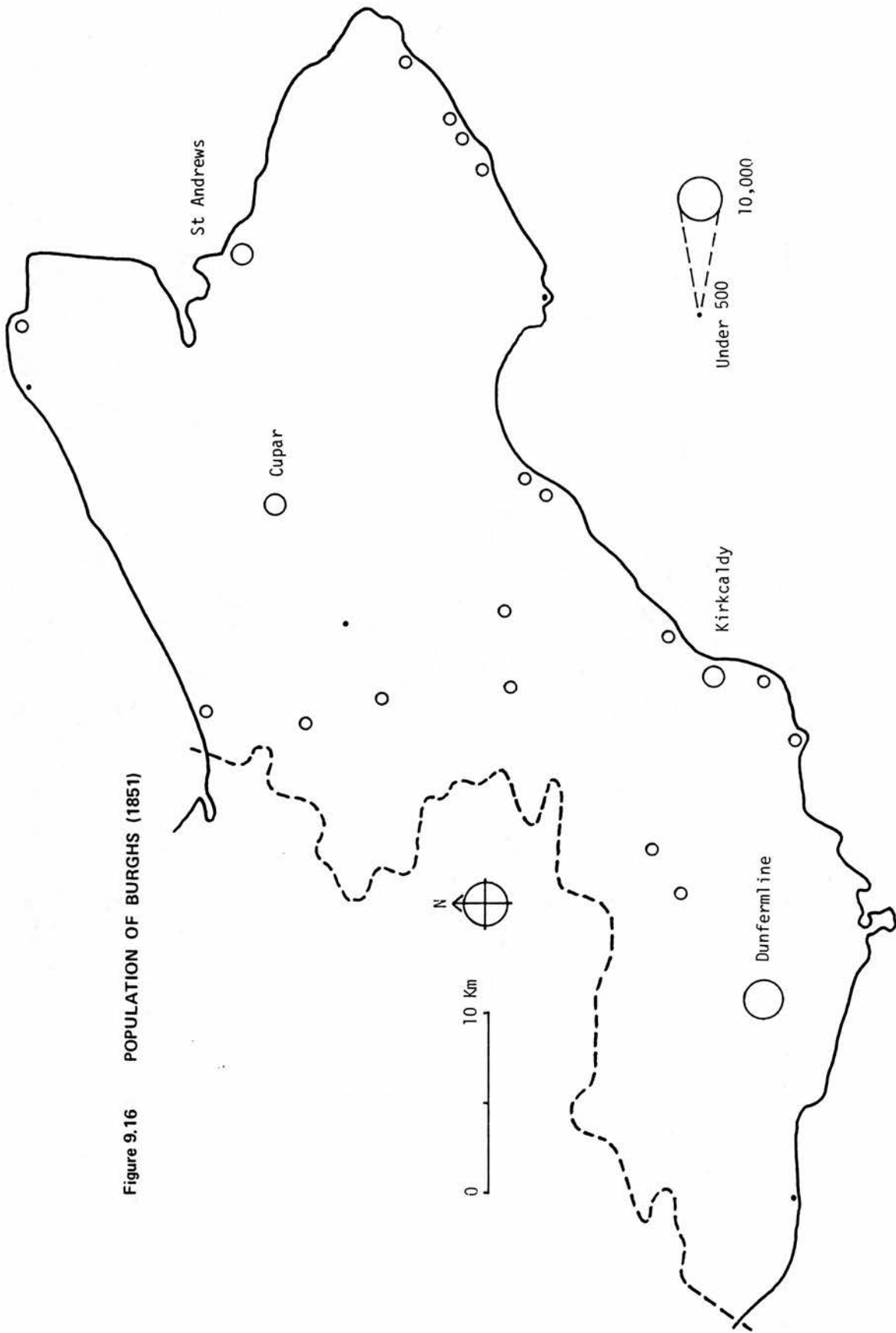


Figure 9.16 POPULATION OF BURGHS (1851)

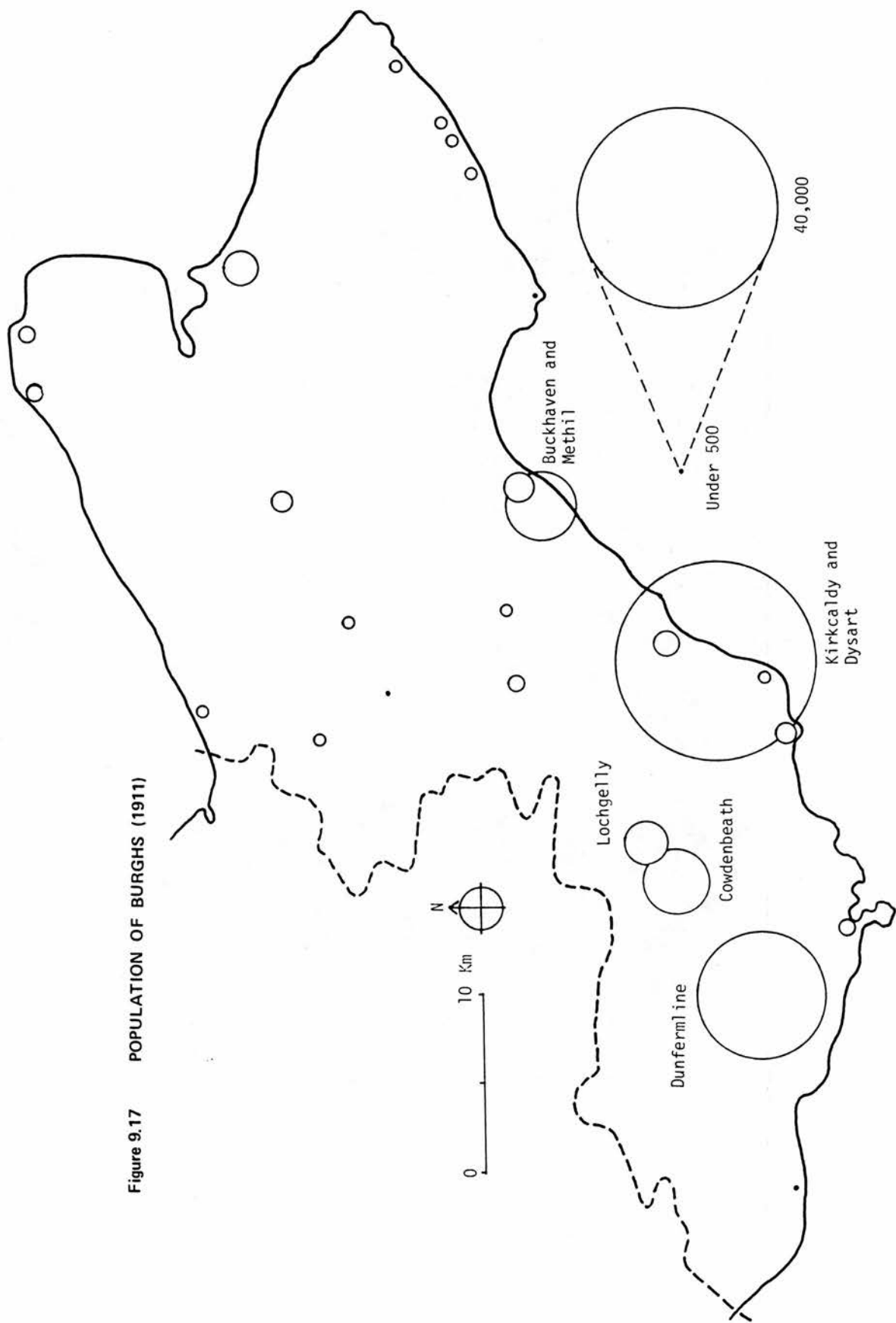
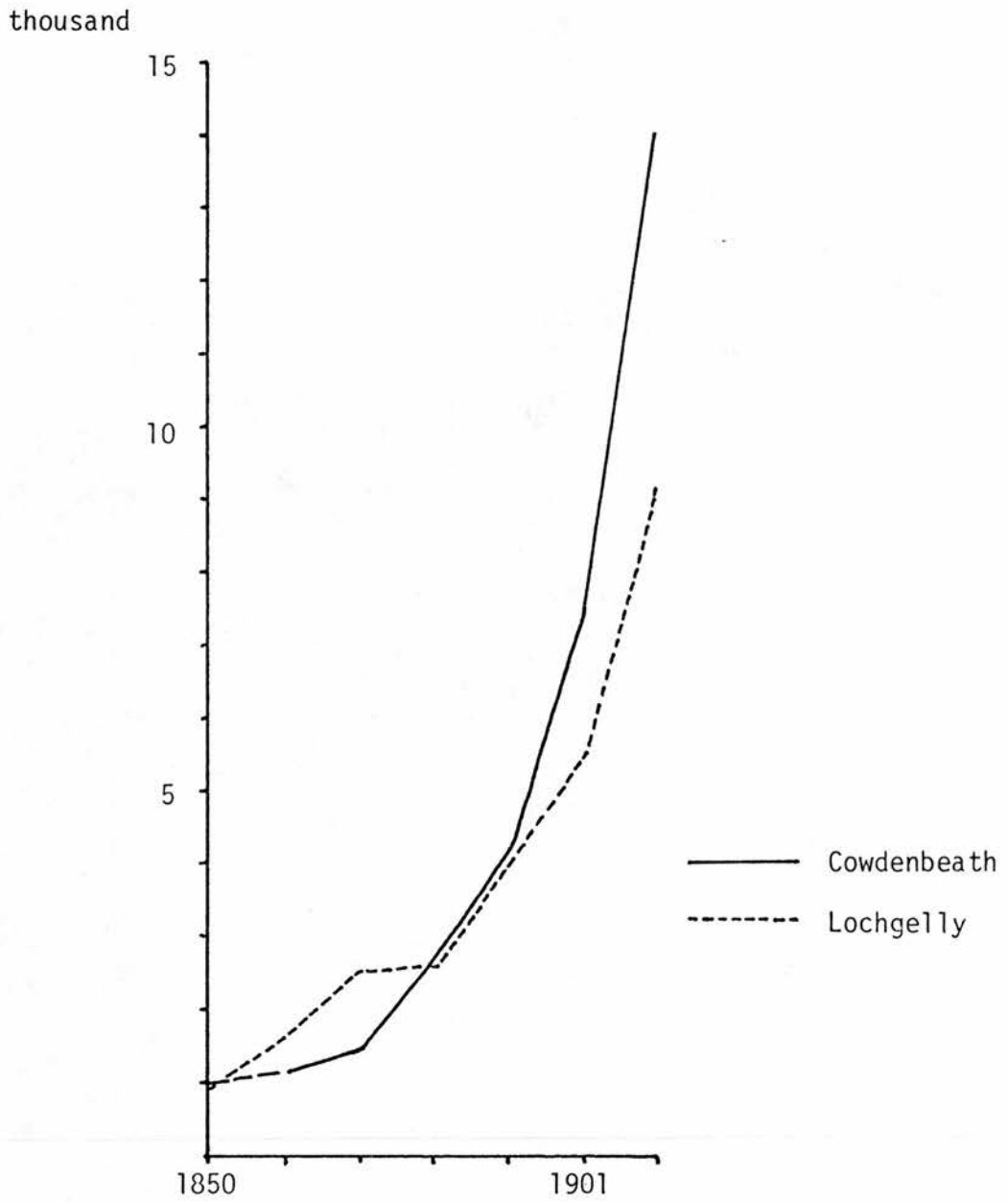


Figure 9.17 POPULATION OF BURGHS (1911)

Figure 9.18 POPULATION OF COWDENBEATH AND LOCHGELLY (1851–1911)



CHAPTER 10 - CONCLUSIONS: THE PROCESS OF
TECHNOLOGICAL INNOVATION

The foregoing chapters have examined the process of technological change in the different aspects of coal mining in Fife, and we have attempted to show that there was a close relationship between the rise of that industry and the more general regional development of the county. However, we have still to provide a coherent explanation for the process of technological innovation, and the following discussion will attempt to assess how far this may be done.

In our discussion it is necessary to make more explicit some aspects of the economic milieu within which innovation took place. While they have been implied in much of what has already been said about individual innovations, for example with reference to their costs, these economic influences must now be viewed as an integrated whole. Consequently, our discussion will examine changing outputs, costs of production, productivity and investment, illustrated with particular reference to the case of Halbeath colliery in the mid nineteenth century. We will then try to adopt the wider view of technological innovation in the Fife coal industry to see whether any general explanation could be useful in elucidating the Fife case. Specifically, we will consider the Kondratieff cycle.

Technological innovation in the Fife coal industry was associated with rapidly expanding production, and before looking at the relationship between technology and output we must try to identify the main features of the latter. Figure 10.1 shows Fife's changing coal output throughout a period of some 160 years. Although estimating output for any time before the mid nineteenth century is fraught with difficulty, it is felt that the estimates given here are reasonable ones.

That for about 1840 was made mainly on the basis of the New Statistical Account, Chalmers' account of Dunfermline¹ and contemporary reports such as those found in the Cadell of Grange papers². The evidence suggests that Fife's output at this time must have been in the region of 500,000 tons (508,000 tonnes) per annum. For the period around the beginning of the nineteenth century we have used data mainly from the Old Statistical Account and from the series of reports by Robert Bald which run from 1810 to 1825³. The evidence here points to an output about 1800 of some 400,000 tons (406,400 tonnes) per annum.

While Nef thought it unlikely that the annual output of Fife was less than 250,000 tons (254,000 tonnes) at the close of the eighteenth century⁴, our figure is clearly much higher than this. On the other hand, some confirmation that our estimate is perhaps of the right order comes from Duckham's figure of a possible 300,000 to 350,000 tons (304,800 - 355,600 tonnes) per annum by 1800⁵. To estimate the total output for any time earlier than about 1790 is to introduce an element of guesswork of such proportion as to render the exercise rather pointless. However, in the interests of stimulating further research, it could be pointed out that the limited evidence available would suggest a possible upper limit of output from Fife about 1750 which was of the order of 250-300,000 tons (254-304,800 tonnes) per annum.

Figure 10.1 shows that output rose gently until about 1840, when a definite steepening of the curve may be observed. Throughout the second half of the nineteenth century output continued to increase at an ever faster rate until the peak of 1914. There is also some reason to believe that a significant increase in output may have taken

place in the late eighteenth century. For example, figures from Balbirnie for the second half of the century indicate an average annual output of 8,427 tons (8,562 tonnes) for 1740-63, 9,343 tons (9,492 tonnes) for 1763-77 and 11,201 tons (11,380 tonnes) for 1778-92⁶. Also, in our earlier discussion of the export of coal we noted that shipments, for example at Kirkcaldy, expanded considerably at about this time⁷. Since alternative markets were not running down, these increased shipments must represent coal which would otherwise have been left underground. In other words, output increased.

Apart from these apparent changes in long-term output trends which occurred in the 1780s and about 1840 (to which dates we will refer again in our consideration of the Kondratieff cycle), there is little more that the data can tell us, except perhaps the self-evident point that the huge rise in output during the late nineteenth century must have come about as a result of the application of impressive new mining technology or of the recruitment of large numbers of additional workers, or possibly of both.

It was felt, therefore, that some short-run series of output figures might show up relevant points if expressed as percentage increases rather than absolute tonnages. The Fife output figures for the period 1870-1914 were examined in this way but showed little variation⁸. A second series, the outputs for Lumphinnans colliery 1852-77, was examined in detail, but no particular pattern was evident, and the only specific relationship to emerge was that the output of this particular colliery was to a large extent influenced by the demand from the local iron furnaces⁹. The third series of output figures related to the Fordell pits between 1835 and 1914, but no pattern was discernible¹⁰.

A fourth series, that for the output of the Lochgelly Iron and

Coal Company 1841-1910, proved much more interesting¹¹. Percentage increases in output were calculated over each decade and the results drawn on a graph (see figure 10.2). A remarkable wave pattern is evident, which shows a high percentage increase about 1860, gradually slowing down to an increase in output of only about 15% between 1880 and 1890, and then rising again as the century draws to a close. Of course, we must beware of drawing any firm conclusions from a comparatively minor piece of evidence, and we must recall that only one of the four short-run series actually produced any identifiable pattern. However, what we can say is that this particular set of figures show a sort of cyclical variation in the rate of increase, with a periodicity of about 60 years. We may also note here that the periodicity of the 'Lochgelly' wave is remarkably coincident with that of the Kondratieff cycle.

By increasing output, even an expensive technological innovation could substantially reduce the costs per unit of production. For example, at Pitfirrane in 1773 each doubling of output was calculated to reduce the costs of working, carriage and shipping by 6d per ton¹², and at Halbeath, a calculation for 1851 puts the cost of raising 20,000 tons (20,320 tonnes) at 3s per ton but of raising 30,000 tons (30,480 tonnes) at 2s 10d per ton¹³. Landale's view was that the low output of Halbeath about this time led to an unacceptably high oncost per ton¹⁴. The fact that output and unit cost have an inverse relationship is shown very clearly in the case of Cluny colliery in 1752¹⁵. Figure 10.3 shows the weekly output and cost per ton for a period of 32 weeks. Here, the term 'oncost' appears to be a reference to the total costs of production, and it is very clear that weeks of low output are also, most emphatically, weeks in which the cost per ton is high. The converse is also true. Consequently, by

increasing output technological innovation also had the effect of reducing unit costs.

Practical examples of the relationship between innovation, output and costs are not hard to discover, and in longwall innovation, particularly, we find a useful illustration. First, there is the obvious advantage of removing almost all the coal in a single working, which was such a beneficial change in terms of output that even the systematic robbing of pillars was superseded. Additionally, longwall working eliminated the risk of 'crush' (collapse) in the workings such as that which hampered output from the Six-foot seam at South Comrie in 1857¹⁶. Longwall, too, allowed the introduction of coal cutting machines, such as the one at Dundonald which quintupled the daily output of the colliery¹⁷. Less directly, longwall working allowed the economical mining of thin seams so that there was less need for costly new winnings to be made.

The role of the steam engine in expanding output and keeping down costs is perhaps most neatly encapsulated in a report on Fordell in 1817 in which Bald criticised the employment of only horse-gins for winding. Two steam drawing engines would reduce the expenses of winding by half and without them, Bald felt that a large output would not be possible except at a very great extra cost¹⁸. Clearly, Bald saw the function of this particular innovation as producing more coal at less cost.

On the other hand, just because the techniques for high output were available does not necessarily mean that they were always used. The technology had to operate within an economic climate which sometimes decreed that output remained well below the capability of a colliery. For example, in 1851 Landale saw Halbeath colliery as "the best subject in the West of Fife, fitted and ready to produce 60,000 tons a year",

but output remained at the "preposterously small" figure of less than 19,000 tons (19,304 tonnes), which we have already identified as the reason for comparatively high costs per ton¹⁹. Obviously, Landale thought that there was no good reason for the low output. In other cases a higher output was technically possible but there were difficulties in carrying the coal to market. For example, the Auchterderran area was thought immediately capable of raising ten times its current output were rail transport to come to that part of Fife²⁰, and Capleedrae colliery in 1872 suffered from a restricted output because it depended on carting as a means of transport²¹. At Cuttlehill, too, the William pit was producing below its capacity, with an output of less than 20,000 tons (20,320 tonnes) per annum which "can with ease be greatly extended"²².

Over the coalfield as a whole, the technological capability for coal output was still underused during the third quarter of the century. This is partially explained by the widespread diffusion of new methods in the 1840s, resulting in a huge rise in productive capacity but not immediately reflected in a comparable rise in output. Some confirmation of this view is found in a table of output figures for 13 West Fife collieries, undated but apparently from about 1850²³. Here, the "present output" totals 379,000 tons (385,064 tonnes) and the "probable increase" is 295,000 tons (299,720 tonnes). Over what period this increase was expected to take place is not clear, but the implication is that this rise in output of about 78% would take place using the coal mining technology already known and in use. In other words, growth in output was at that stage more a function of the state of the market than it was of the state of mining technology. Also, it was not technological limitations but shortage of labour which kept output down at Lumphinnans in 1871:

"Owing to the short time movement having been adopted at most of the collieries, and to the scarcity of miners the outputs have as a rule been considerably curtailed"²⁴

The economic climate of technological innovation is perhaps best reflected in a consideration of one particular case, where production costs, selling prices, profits and investment elements are brought together during a period of innovative activity. The innovative years of the 1840s and 50s would be a useful period to consider, and we are fortunate in having at least some of the appropriate information for the Halbeath colliery during that time.

Halbeath lies about 3 Km East of Dunfermline, and as well as supplying saltpans had enjoyed a substantial shipping trade from Inverkeithing harbour after the construction of the Halbeath waggonway in 1783. About 1794, some 25,000 tons (25,400 tonnes) per annum were shipped from that port, most of it coming from Halbeath²⁵. By 1812, however, the contemporary accounts suggest that the Halbeath enterprise was somewhat run down. The winning at that time was practically exhausted and the remaining coal only workable at a loss. The main pumping engine remained in good order, although overworked and in need of a new boiler, and other repairs were also required²⁶. Economies had been made in the running of the colliery, so that the stock of necessary materials was by 1812 very small for a coal work the size of Halbeath. Three years later, in 1815, little improvement had taken place and it was pointed out that the uncommonly high degree of "troubles" (dykes and faults) were a source of great expense in working the coal²⁷. At that stage, engineers Grieve and Bald suggested a valuation of the mineral rights at between £50 and £300²⁸.

By mid-century, however, the colliery was in a much more healthy state, the investment in fitting up the Queen pit having provided a

much greater productive capacity. At £9753 for the Engine pit and £602 for the Bye pit, the total cost, including interest, was calculated at about £11,000. Assuming a value of £4,000 at the end of the lease, a depreciation of £7,000 had to be written off. Landale allowed 10% per annum, or £700 a year to be set against the income from sales²⁹. Where output (and therefore income) was higher, the depreciation could be written off more quickly, and this is shown in Henry Cadell's calculation in which an output of 20,000 tons (20,320 tonnes) sees depreciation on machinery at 5%, or a cost of £500 per annum, while on an output of 30,000 tons (30,480 tonnes), depreciation is costed at 7½%, or £750 per annum³⁰. What this means in general terms is that capital investment was most usefully employed, and would pay for itself most quickly, where it made a significant contribution to increasing the output of coal.

Landale's opinion regarding the costs of raising coal at Halbeath was that doubling the output would have the effect of saving 10d per ton, equal to £1,666 per year, and consequently he thought that profitable working was possible³¹. This must have disappointed the lessees of the colliery, Brown, Gordon and Company, who were trying to escape from their obligations on the grounds that Halbeath was unworkable to profit. On the other hand, John Geddes, the mining engineer, pointed out that the important Parrot seam was now worked out and that in the 3½ years between 1847 and 1851 the colliery had obtained a total profit of only £156, no account having been taken for interest on fixed capital or for bad debts. He concluded that the colliery was therefore running at a ruinous loss³². Three factors were responsible for this. First, the working out of the Parrot seam, second the price reductions brought about by competition from coal carried by the railways, and third the impossibility of effecting

adequate sales. These factors, he contends, were outwith the tenant's control, and despite a capital investment totalling over £13,000 they produced a situation in which Halbeath colliery could not be profitable.

Thus it was that the two major technological changes introduced to Halbeath in the 1840s were unable to reduce costs to the extent that the limited sale could cover them adequately. The first innovation, that of longwall working, was made at Halbeath before 1844 and required little capital investment. Nevertheless, the installation of a 200 horse-power pumping engine at the Queen fitting in 1845 represented a substantial part of the investment there, and, compared with the largest (30 horse-power) engine working there just previously, also represented an enormous increase in pumping power. Although these innovations increased the productive capability of the colliery, the nature of the market kept output, and profits, down.

Paying interest on large capital investments like the Queen fitting would not have increased total costs if the employment of capital was able to reduce significantly the cost of labour, but on this point the evidence at Halbeath is inconclusive. For instance, Peddie's figure for the cost of raising 20,000 tons (20,320 tonnes) at Halbeath in 1840 is put at 3s 6d per ton³³, while Cadell's figure for 1851 is 3s per ton³⁴. The limited evidence we have would suggest that wages in the area were, if anything, actually rising at the same time as these costs were falling so the cost reduction must be due to more economic methods of raising the coal³⁵. Longwall operations and greatly improved pumping efficiency could well account for the saving.

In the case of Halbeath, then, we have tried to disentangle at least to some extent the complex web of interrelationships within which

technological innovation took place. However, in looking at Fife as a whole the yardstick of productivity may be a more useful tool.

The total numbers employed in the Fife coal industry between 1800 and 1914 are shown in figure 10.4. By the end of the eighteenth century, some 2,800 people are estimated as having been employed, a figure which is very much the same as that given for 1842 in the report of the Children's Employment Commission³⁶. Given this, the 25% rise in output which we have calculated between those years must be the result of improved working practices. After mid-century the increase in numbers employed is roughly comparable with the increasing output of coal, rising to a total of about 30,000 employees by 1914.

Figure 10.5 shows the amount produced per person per annum. Unfortunately, information prior to about 1800 is too fragmented for useful generalisation, and figures often refer to output per collier (hewer), leaving the reader to assess how many other employees were involved in haulage, winding and various oncost tasks. Fortunately, this problem does not occur after about the middle of the nineteenth century so our graph may be regarded as being relatively more accurate after that time. We must still be aware, however, that output per man per year is a crude measure of productivity, and will reflect factors other than the effect of new mining technology. Bearing this in mind, most noteworthy in figure 10.5 is the fact that the trend in productivity changed about 1880, following an increasingly steep rise since 1840. The plateau was followed by a sudden fall during the strike of 1894. There was then a further rise during the 1890s and a fall to 1914. From a mining technology viewpoint, we may usefully examine three main factors in the search for an explanation.

First the tendency to diminishing returns has been cited by

Taylor as contributing to the downturn in UK productivity from the 1880s onwards³⁷. While the long term trend to diminishing returns was bound to appear in Fife eventually, it is not felt to be a very satisfactory explanation for the county's productivity changes in the 30 years after 1880. There are two reasons for this. First, it does not explain the rise in Fife's productivity which occurred after recovery from the 1894 strike, and second, the rise in cost per ton which we would expect with diminishing returns does not appear in the Fife figures. In fact, if anything, the cost per ton fell during the 1880s. For example, the Fife Coal Company was paying a cost per ton of 5s in 1877 but only 4s in 1889³⁸.

The second factor which may help to explain the productivity changes is the question of the timing of innovations. The main diffusion of innovations occurred in mid-century and by about 1860 or 1870 was substantially over. This means that the increase in productivity which followed the spread of the new methods could not be sustained, and a continued growth in output for the important shipment market could only be achieved by expanding the workforce. As a result, productivity levelled off. The increase in output per man was possible up to about 1880 by using the spare technological capacity which had been built up in mid-century and without employing many more people. After 1880, that capacity was already in use and the workforce had to increase.

The third factor is the nature of the work force itself. The huge growth in numbers employed which occurred between 1880 and 1914 must have meant a reduction in the average level of mining skill and experience. We have already noted in our discussion of population growth that in 1907, only 68% of the workforce at Bowhill colliery had begun their working lives underground³⁹.

While these three factors together explain to a great extent the altered trend in productivity after about 1880, they fail to account for the rise evident in the last few years of the nineteenth century, and here we have a problem. During the late nineteenth century, productivity in Fife was consistently higher than for the UK as a whole (see figure 10.5). Although the trends in all three graphs are similar and the effects of the strike are very evident, in the 1890s productivity in Fife rose by about 19% overall while the Scottish figure rose only marginally over the decade and that for the UK remained virtually static. Looking at the figures another way, Fife in the 1890s saw a smaller percentage increase in workforce than the decades before and after, and also saw a larger percentage increase in output than the decades before and after (figure 10.6). What this means is that first, the 1890s were special within Fife, reversing the trend in productivity evident after 1880. Second, this made Fife stand out against the trend in the coal industry as a whole, both in Scotland and the UK.

The explanation for this state of affairs is not likely to be a simple one, but two main factors seem to be important. First, the strike of 1894 resulted in a wage reduction and a temporary fall in the numbers employed. Although numbers rose again, recovery was scarcely as rapid as the speedy recovery of output which took place after the strike. Thus it was mainly the second half of the decade which produced Fife's rise in productivity. The question of why this rise took place in Fife more emphatically than throughout the industry as a whole may be answered by a look at where the new output was coming from. It was the Fife Coal Company. This company accounts for some 66% of the increase in Fife's production during the 1890s, the company itself

increasing output by 153% compared with only 23% for other Fife producers, and must therefore be seen as the major agency in the burgeoning production of this coalfield at the very end of the century. How the company achieved this increase is not entirely clear. Few major innovations were made or being diffused in the late 1890s, except perhaps the introduction of compound steam engines for pumping. Coal cutters were not taken up enthusiastically until after 1900, when they evidently failed to prevent a fall in productivity. This is not entirely surprising, since Jevons makes it clear that their ability to reduce the workforce was limited⁴⁰. The introduction of electricity was certainly taking place in the 1890s, but in an industry where steam haulage was already widespread, electric power could hardly affect productivity to the extent identified. In any case, these innovations were not peculiar to Fife, and we are after all trying to explain a Fife phenomenon. Perhaps we can suggest one possible explanation. During the 1890s, the Fife Coal Company was busy applying modern mining technology to new sinkings. It was not the innovations themselves which were so important, but the application of techniques already in widespread use to large new winnings. The Aitken pit is a case in point. Sunk in 1896, the Aitken commenced winding coal the following year, and by 1900 was producing something of the order of 500,000 tons (508,000 tonnes) a year⁴¹. Cunningham makes it clear that all the most up-to-date methods were employed in a pit purpose-built for them⁴². Taken together with large new winnings at Glencraig, Bowhill, Lumphinnans and Lochhead, the impetus to productivity given by a giant modern pit like the Aitken should not be underestimated. However, this explanation does depend on these developments being rather more marked in Fife than elsewhere, so confirmation must await detailed

comparisons with other coalfields. However, the huge new winnings of the 1890s were allied with a sophisticated rail network purpose-built for coal traffic and serving the most up-to-date shipping terminal at Methil. This is perhaps where Fife stood out from other coalfields. Here, we had the application of a large-scale, integrated system for the production and transport of coal and this is what we see reflected indirectly in productivity changes.

Nevertheless, over the longer term we still have to identify a possible explanation for technological innovation in the Fife coal industry. Part of the answer may lie in the long-term business cycle. Although the so-called 'long wave' had been previously described, the cycle is named after Nikolai Kondratieff, who made a major contribution to the development of the idea in his paper of 1926⁴³. Considerable controversy still surrounds the hypothesis, but the emphasis now seems to have shifted from whether the Kondratieff cycle really exists to a debate about the possible causes.

In 1939 Schumpeter put forward a technological theory for the origins of the wave and recent work has given this explanation a new impetus⁴⁴. Briefly, the theory may be summarised as follows. Long-term trends in prices, output and employment suggest that capitalist economies follow a regular long cycle. Kondratieff identified three cycles by 1926:

- | | | |
|--------------|---|-------------------------|
| First cycle | - | rise about 1790 to 1814 |
| | | fall about 1814 to 1850 |
| Second cycle | - | rise about 1850 to 1872 |
| | | fall about 1872 to 1896 |
| Third cycle | - | rise about 1896 to 1917 |
| | | fall about 1917 to - |

Van Duijn names four stages in these cycles as being Prosperity, Recession, Depression and Recovery, and Schumpeter explained them in terms of technological innovation⁴⁵. It is argued that each long wave represents the economic consequences of a new group of technologies. While inventions emerge at a fairly even rate, innovations (the application of inventions to the creation of new products or the improvement of processes) tend to cluster at 50 or 60 year intervals (figure 10.7). These clusters appear to coincide with Van Duijn's Depression phases, and it is argued that it is the surge of innovation which stimulates the subsequent Recovery. The innovation surge ultimately becomes exhausted and Depression ensues, thus creating the climate for a new surge of innovation. Considerable debate exists about this explanation, with Forrester, for example, seeing the cluster of innovations as a consequence of the long wave rather than a cause⁴⁶.

In the context of the Fife coal industry, our problem is to determine whether the process of technological innovation may be seen as related to the Kondratieff cycle. First, it was necessary to identify any innovation clusters. The dates of 23 major innovations were plotted and the results are shown in figure 10.8. No particular clusters are evident, although a small cluster might be recognised between 1810 and 1821. However, if we regard the period of fastest diffusion of an innovation as a better measure of its take-up by businessmen, then the second part of figure 10.8 is more relevant. This shows the periods of fastest diffusion for the 18 major innovations for which we have enough data. While some of these dates are to a certain extent subjective, most are based on a fairly large number of known cases of take-up. The frequency of take-up of all the innovations is shown in the third part of the figure, and there is some

evidence of slight clustering in the 1780s and in the 1840s and 50s. Most significant is the fact that these dates are the very periods when Schumpeter would tell us to expect innovation, with the Kondratieff cycles beginning about 1790 and 1850. Taken together with the two periods of increase in Fife's total output and with the cyclical variation in the rate of increase of production from the Lochgelly Iron and Coal Company, both of which will now be seen as remarkably coincidental with the Kondratieff pattern, we can propose that in the technological explanation for the theory of long waves we find a hypothesis which helps to a certain extent to explain the process of technological innovation in the Fife coal industry.

However, we cannot ignore the role of the individual entrepreneur, for it is clear that throughout our consideration of technical advances the readiness of Fife coalmasters to innovate was very evident. From the seventeenth-century pits of Culross and Sir George Bruce to the great winnings of the twentieth-century Fife Coal Company under Charles Carlow, we find the energy and enthusiasm of individuals playing an important role. Nevertheless, their innovative work was carried out within the bounds set both by the economic forces of their day and by the technology at their disposal, so even the entrepreneurial factor may be said to be subject to the fluctuations of the business cycle.

In summary, we have examined in detail the process by which a number of technological changes were implemented in the Fife coal industry during the 164 years of its major growth period, and we have seen that the technology-led development of the industry has had profound implications for the changing geography of Fife, particularly in the South-Western part of the county. We have concluded that the process of technological innovation may owe a certain amount to its

relationship with the long-term business (Kondratieff) cycle. Changes in mining technology had brought the Fife coalfield a very long way indeed from 1526, when Hector Boece noted simply that:

"In Fiffe are won black stanis quilk hes sa
intollerable heit quhen they are kendillit, that
they resolve and meltis irne....."⁴⁷

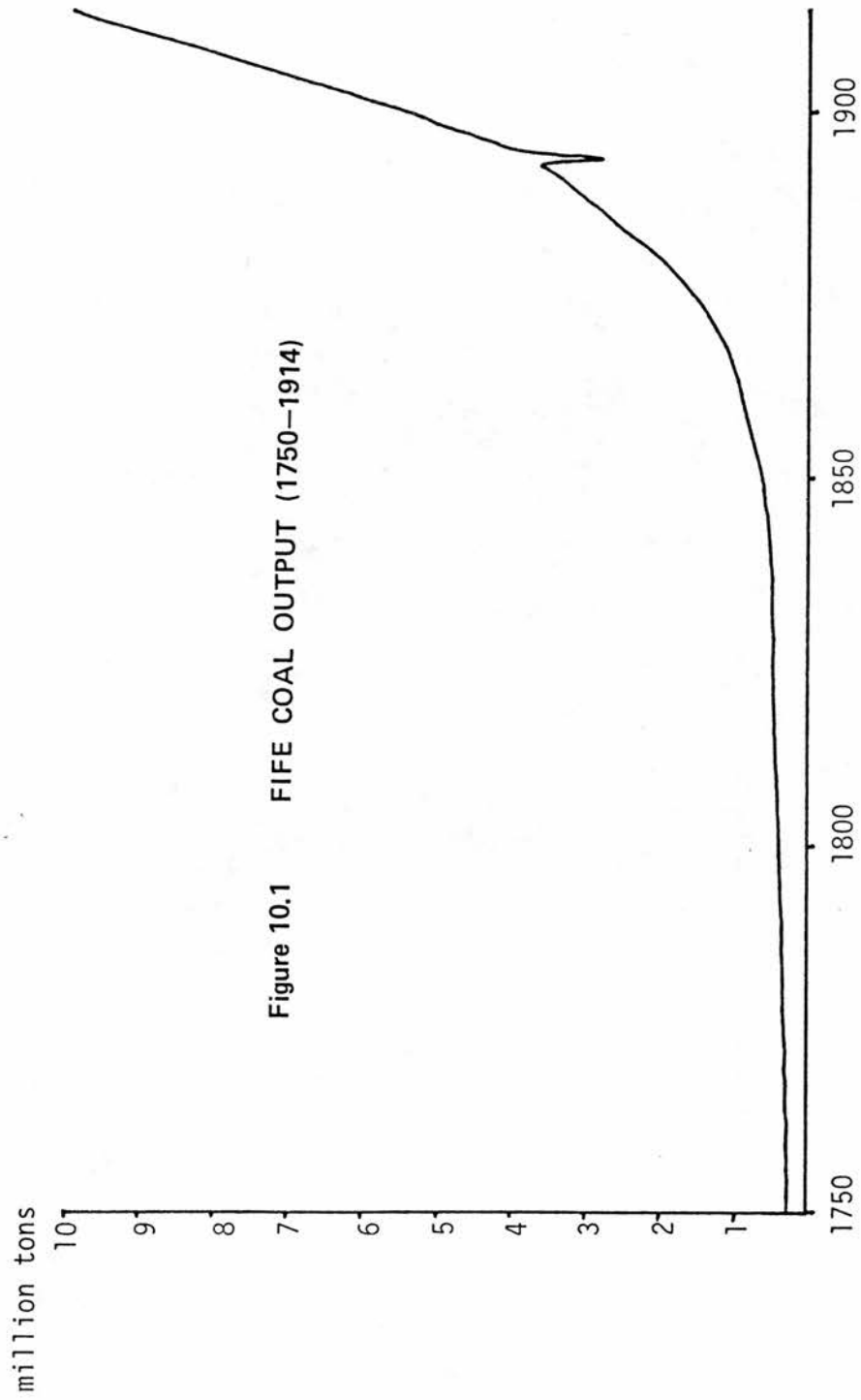
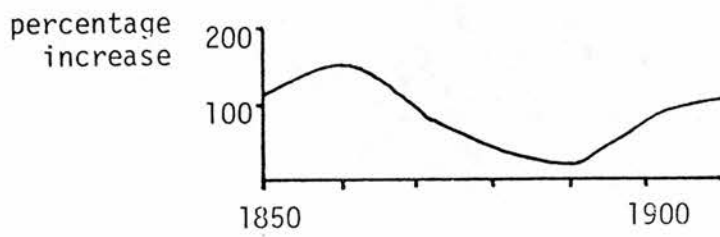


Figure 10.1 FIFE COAL OUTPUT (1750-1914)

Figure 10.2

DECENNIAL PERCENTAGE INCREASE IN OUTPUT OF THE LOCHGELLY
IRON AND COAL COMPANY (1850-1910)



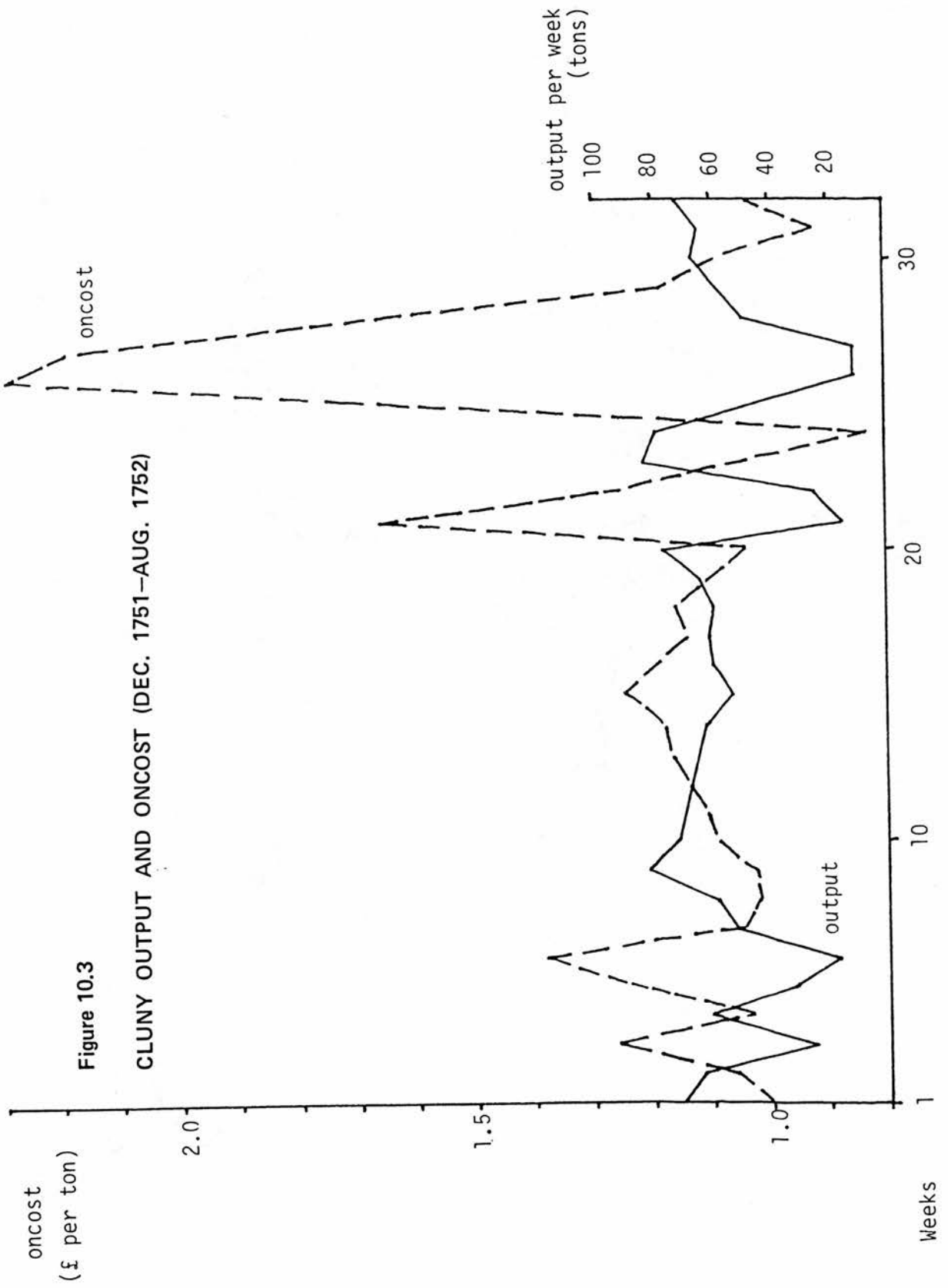


Figure 10.4 NUMBERS EMPLOYED IN THE FIFE COAL INDUSTRY (1800–1914)

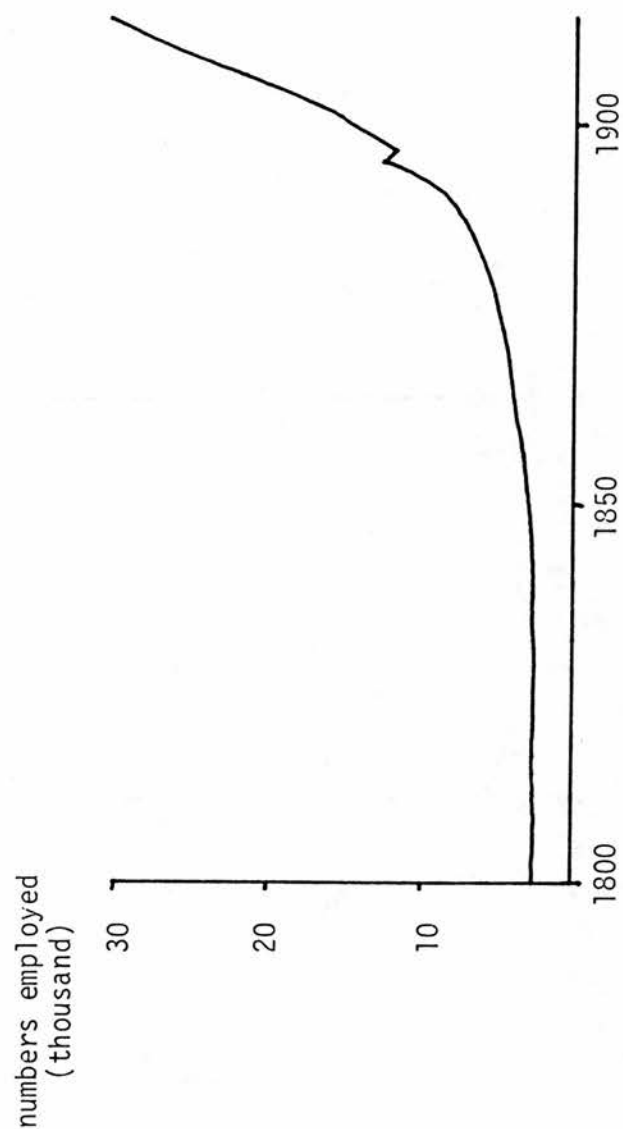


Figure 10.5 PRODUCTIVITY (1800–1914)

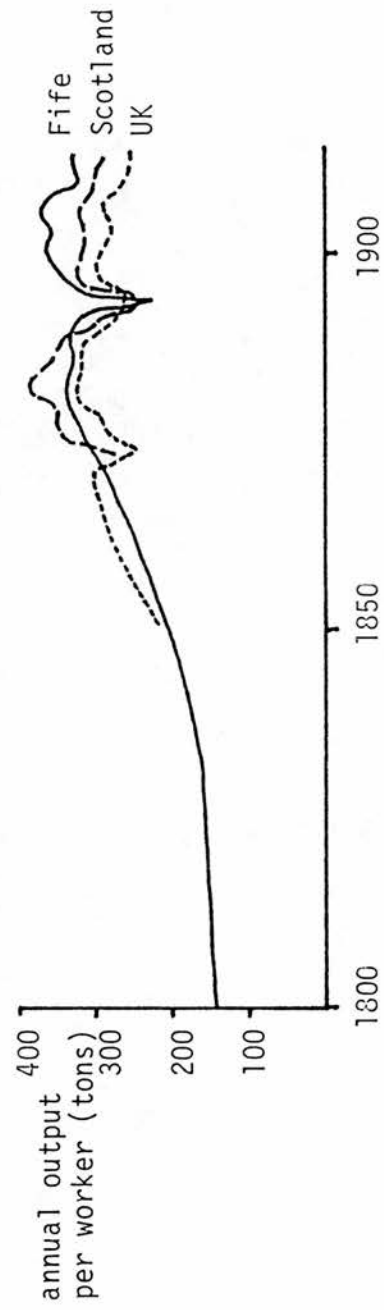


Figure 10.6 **CHANGING EMPLOYMENT AND OUTPUT (1860–1910)**

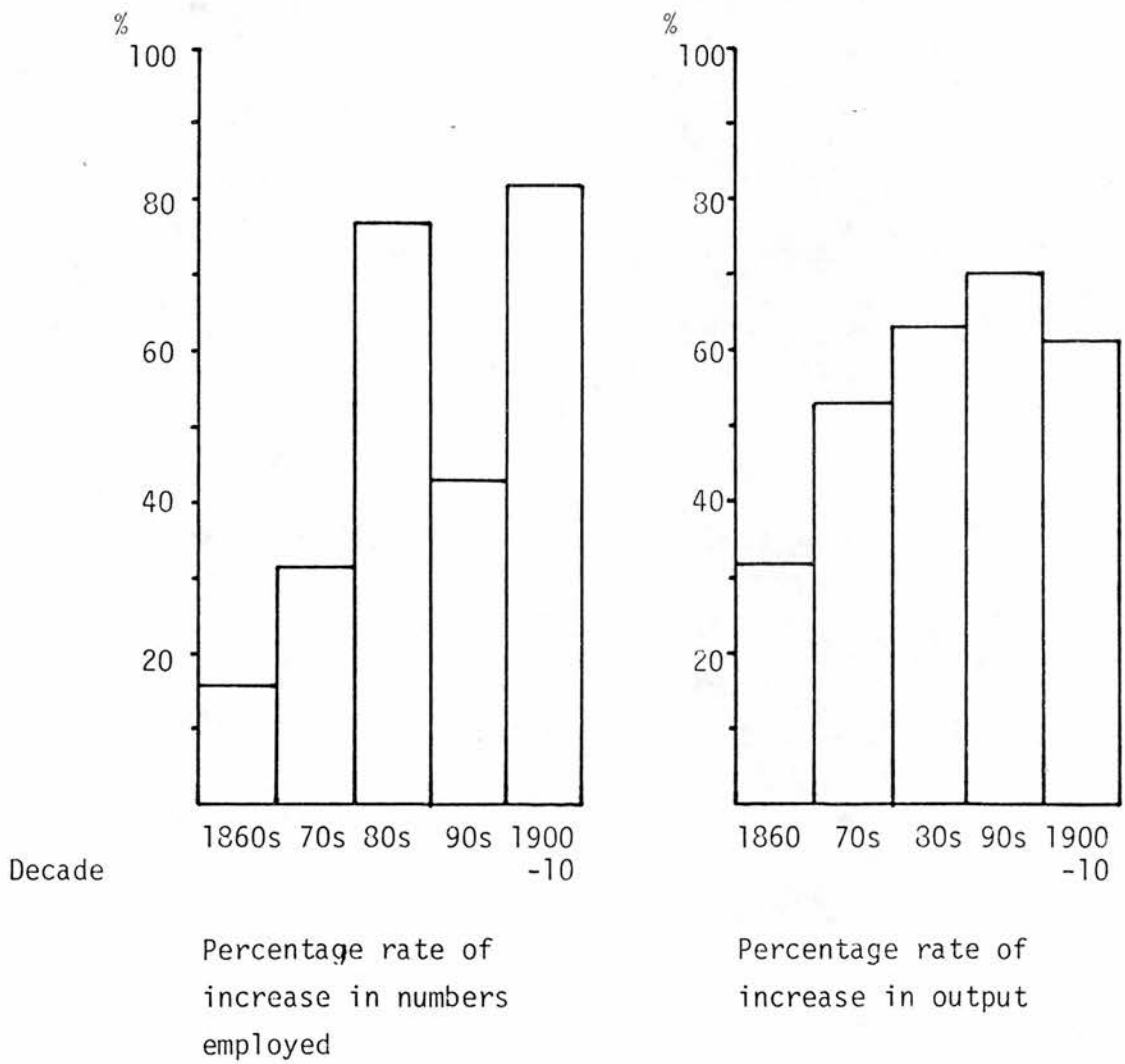


Figure 10.7 FREQUENCY OF INNOVATION

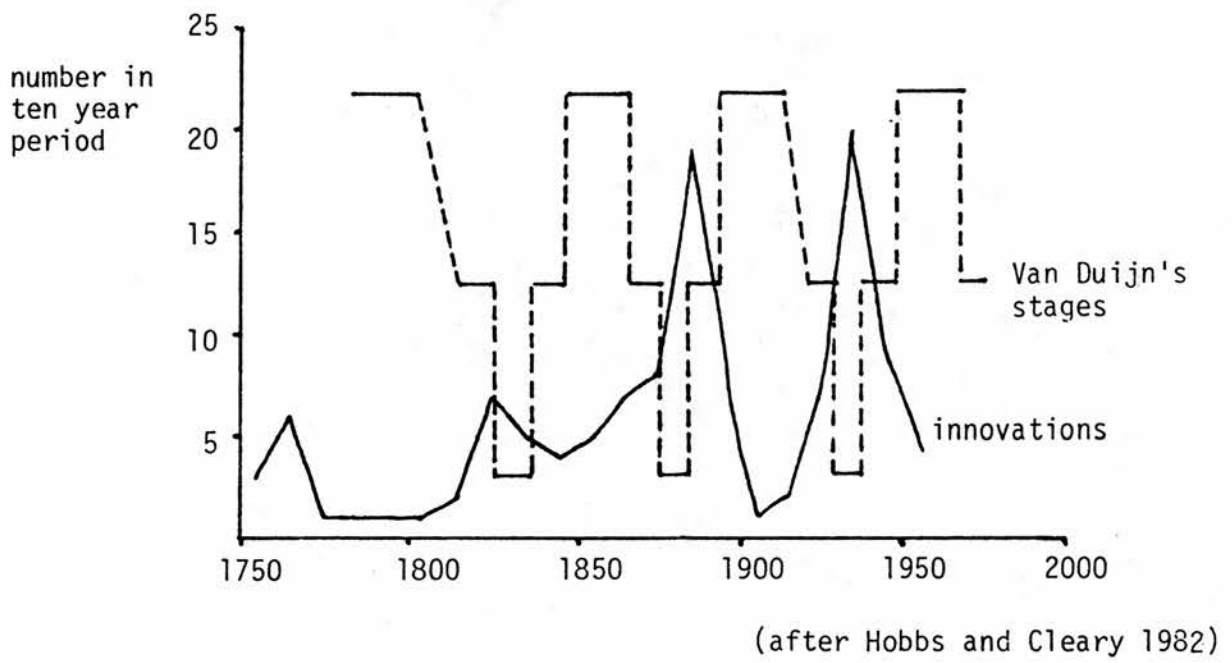
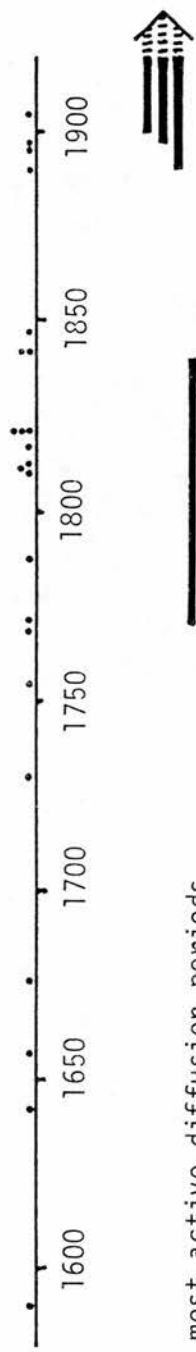
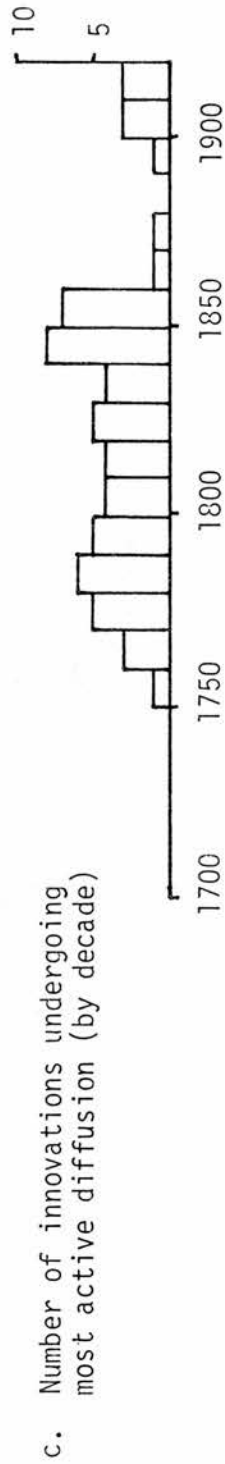


Figure 10.8 TECHNOLOGICAL INNOVATION IN THE FIFE COAL INDUSTRY

a. First innovation dates in Fife for 23 major technological innovations



b. The most active diffusion periods for 18 major innovations



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OSA - Old Statistical Account
 NSA - New Statistical Account
 SRO - Scottish Record Office
 RHP - Register House Plans
 NLS - National Library of Scotland

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